PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 80	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
International application No. PCT/GB 99/ 04150	International filing date (*day/month/year*) 15/12/1999	(Earliest) Priority Date (*day/month/year*) 16/12/1998
Applicant CAMBRIDGE DISPLAY TECHNOLOGY LTD. et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 4 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

      [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

      [ ] contained in the international application in written form.
      [ ] filed together with the international application in computer readable form.
      [ ] furnished subsequently to this Authority in written form.
      [ ] furnished subsequently to this Authority in computer readble form.
      [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
      [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   [ ] the text is approved as submitted by the applicant.
   [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

   [X] as suggested by the applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)

The abstract is changed as follows:

An organic light-emitting device comprising a light-emissive organic layer(8) interposted between first(4) and second(12) electrodes for injecting charge carriers into the light-emissive organic layer(10), at least one of said first and second electrodes comprising a plurality of layers including a first electrode layer(10) having a high resistance adjacent the surface of the light-emissive organic layer(8) remote from the other of the first and second electrodes, said first electrode layer(10) comprising a high-resistance material selected from the group consisting of a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 99/04150

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L51/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 647 813 A (KITABAYASHI MOTOI ET AL) 3 March 1987 (1987-03-03) the whole document ---	1-3,7,8, 10-13, 15,17, 22,56-59
Y	US 5 739 545 A (HAIGHT RICHARD ALAN ET AL) 14 April 1998 (1998-04-14) the whole document ---	1-3,7,8, 10-13, 15,17, 22,56-59
P,X	EP 0 901 176 A (CAMBRIDGE DISPLAY TECH) 10 March 1999 (1999-03-10) abstract --- -/--	1-3

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 March 2000	31/03/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Laere, A

1

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	EP 0 903 964 A (EASTMAN KODAK CO) 24 March 1999 (1999-03-24) column 4, line 22 -column 5, line 8	15, 18-22,59
P,A		43-47, 52-54
A	WO 97 32452 A (UNIAX CORP) 4 September 1997 (1997-09-04) page 13, line 7 -page 16, line 20	1-3
A	GYOUTOKU A ET AL: "Organic electroluminescent dot-matrix display using carbon underlayer" PROCEEDINGS OF THE 1997 INTERNATIONAL CONFERENCE ON ELECTROLUMINESCENCE OF MOLECULAR MATERIALS AND RELATED PHENOMENA;FUKUOKA, JPN MAY 21-24 1997, vol. 91, no. 1-3, 21 May 1997 (1997-05-21), pages 73-75, XP000890057 Synth Met;Synthetic Metals Dec 1997 Elsevier Science S.A., Lausanne, Switzerland page 73-75, paragraph 3	1-3
A	JABBOUR G E ET AL: "ALUMINUM BASED CATHODE STRUCTURE FOR ENHANCED ELECTRON INJECTION INELECTROLUMINESCENT ORGANIC DEVICES" APPLIED PHYSICS LETTERS,US,AMERICAN INSTITUTE OF PHYSICS. NEW YORK, vol. 73, no. 9, 31 August 1998 (1998-08-31), pages 1185-1187, XP000781203 ISSN: 0003-6951 abstract	5-9,22, 58,59

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 99/04150

Patent document cited in search report	Publication date	Patent family member(s)	Publication dat
US 4647813 A	03-03-1987	JP 1454860 C	25-08-1988
		JP 60124397 A	03-07-1985
		JP 63000918 B	09-01-1988
		DE 3444769 A	20-06-1985
		FR 2556548 A	14-06-1985
		GB 2152751 A,B	07-08-1985
US 5739545 A	14-04-1998	EP 0856896 A	05-08-1998
		JP 10223377 A	21-08-1998
EP 0901176 A	10-03-1999	NONE	
EP 0903964 A	24-03-1999	JP 11149985 A	02-06-1999
WO 9732452 A	04-09-1997	US 5798170 A	25-08-1998
		AU 2192197 A	16-09-1997

F ..TENT COOPERATION TREA.. .'

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 07 August 2000 (07.08.00)	
International application No. PCT/GB99/04150	**Applicant's or agent's file reference** 80
International filing date (day/month/year) 15 December 1999 (15.12.99)	**Priority date** (day/month/year) 16 December 1998 (16.12.98)
Applicant CARTER, Julian, Charles et al	

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International Preliminary Examining Authority on:

   10 July 2000 (10.07.00)

   [ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was
   [ ] was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Zakaria EL KHODARY Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

HARTWELL, Ian Peter
CAMBRIDGE DISPLAY TECHNOLOGY LTD,
Greenwich House
Madingley Rise
Madingley Road
Cambridge CB3 OHJ
GRANDE BRETAGNE

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing *(day/month/year)* 09.03.2001

Applicant's or agent's file reference
CDT 080 PCT

IMPORTANT NOTIFICATION

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB99/04150	15/12/1999	16/12/1998

Applicant
CAMBRIDGE DISPLAY TECHNOLOGY LTD. et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

   The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

   Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

   For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

DOCKETED
By: S.h F
Date: 14/3/01
Action Type: IPER Received
Case Date:

Name and mailing address of the IPEA/
European Patent Office
D-80298 Munich
Tel. +49 89 2399 - 0 Tx: 523656 epmu d
Fax: +49 89 2399 - 4465

Authorized officer
Hopwood, S
Tel. +49 89 2399-2429

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference CDT 080 PCT	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/GB99/04150	International filing date *(day/month/year)* 15/12/1999	Priority date *(day/month/year)* 16/12/1998
International Patent Classification (IPC) or national classification and IPC H01L51/20		
Applicant CAMBRIDGE DISPLAY TECHNOLOGY LTD. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 19 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☒ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☒ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☒ Certain defects in the international application
   VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
10/07/2000	09.03.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Götz, A Telephone No. +49 89 2399 2498

I. Basis of the report

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).)*:

   Description, pages:

   1-25 as published

   Claims, No.:

   1-59 as published

   Drawings, sheets:

   1/3-3/3 as published

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

II. Priority

1. ☐ This report has been established as if no priority had been claimed due to the failure to furnish within the prescribed time limit the requested:

   ☐ copy of the earlier application whose priority has been claimed.

   ☐ translation of the earlier application whose priority has been claimed.

2. ☐ This report has been established as if no priority had been claimed due to the fact that the priority claim has been found invalid.

Thus for the purposes of this report, the international filing date indicated above is considered to be the relevant date.

3. Additional observations, if necessary:
see separate sheet

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

   ☐ restricted the claims.

   ☐ paid additional fees.

   ☒ paid additional fees under protest.

   ☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☒ not complied with for the following reasons:
   see separate sheet

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

☒ all parts.

☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	9, 23-58
	No:	Claims	1-8, 10-22, 59
Inventive step (IS)	Yes:	Claims	9, 23-26, 32, 35, 46, 49
	No:	Claims	27-31, 33, 34, 36-45, 47, 48, 50-58
Industrial applicability (IA)	Yes:	Claims	1-59
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

1 Reference is made to the following documents:

D1: PATENT ABSTRACTS OF JAPAN vol. 1996, no. 05, 31 May 1996 (1996-05-31) -& JP 08 008065 A (TOPPAN PRINTING CO LTD), 12 January 1996 (1996-01-12) -& English language translation

D2: US-A-5 739 545 (GUHA SUPRATIK ET AL) 14 April 1998 (1998-04-14)

D3: US-A-4 634 934 (TOHDA ET AL) 6 January 1987 (1987-01-06)

D4: EP-A-0 903 964 (EASTMAN KODAK CO) 24 March 1999 (1999-03-24)

D5: US-A-4 647 813 (KITABAYASHI MOTOI ET AL) 3 March 1987 (1987-03-03)

D6: JABBOUR G E ET AL: 'ALUMINUM BASED CATHODE STRUCTURE FOR ENHANCED ELECTRON INJECTION IN ELECTROLUMINESCENT ORGANIC DEVICES' APPLIED PHYSICS LETTERS, US, AMERICAN INSTITUTE OF PHYSICS. NEW YORK, vol. 73, no. 9, 31 August 1998 (1998-08-31), pages 1185-1187, XP000781203 ISSN: 0003-6951

The documents D1 and D3 were not cited in the international search report.

Re Item II

Priority

2 It is noted that part of the present application (e.g. Fig. 6) was not disclosed in none of the two priority documents.

Re Item IV

Lack of unity of invention

3 Independent claims 1, 5, 10, 15, 16, 18, 27, 39 and 43 are directed to organic light-emitting devices including means for limiting the current flow through any conductive defect in the light-emissive organic layer. The problem to be solved is to reduce the leakage current through conductive defects in the organic light-emissive layer.

Independent claims 22 and 42 are directed to a fabrication method of such a device.

4 Independent claim 23 is directed to a light-emissive device with an electrode layer consisting of a plurality of sub-electrodes, wherein the sub-electrodes are connected via fusible links. The fusible links permit to electrically isolate sub-electrodes by blowing the fusible link. The device is not specified to be organic.

5 As a consequence there are the following independent inventions not linked by a common inventive concept:
i) The organic light-emitting device and fabrication method thereof according to independent claims 1, 5, 10, 15, 16, 18, 22, 27, 39, 42 and 43 and the claims depending on these independent claims.
ii) The light-emissive device according to independent claim 23 and the claims depending on claim 23.

6 The independent inventions i) and ii) provide different solutions for the problem of avoiding excessive current.

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

7 Concerning Invention i)
(cf. Item IV of this communication)

Independent Device Claims of Invention i):

7.1 The subject-matter of independent claim 1 of the present application is not new in the sense of Article 33(2) PCT.
Document D1 discloses:
- an organic light-emitting device (cf. Japanese Application JP 08 008065 A, Fig. 1 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic layer and
- means for limiting the current flow through any conductive defect in said

light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4a and column 4, lines 7-13: the first cathode layer is described as a layer of material of low conductivity which is covered with a layer of high conductivity. The layer of low conductivity limits the current through any conductive defect in the light-emissive organic layer).
Hence D1 discloses all the technical features of claim 1.

It is pointed out that D2 discloses all the features of claim 1, too. The relevant passage is D2, column 3, lines 30-34, from which it is clear that the light-emissive organic device has means for limiting the current flow.

7.2 The subject-matter of independent claim 5 of the present application is not new in the sense of Article 33(2) PCT.
Document D1 discloses:
- an organic light-emitting device (cf. Japanese Application JP 08 008065 A, Fig. 1 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic layer, at least one of said first and second electrodes comprising a plurality of layers (cf. Japanese Application JP 08 008065 A, Fig. 1, the electrode with reference sign 4 consists of layers 4a and 4b) including a first electrode layer (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4a) having a high resistance (cf. Japanese Application JP 08 008065 A, column 4, lines 7-13) adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes (cf. Japanese Application JP 08 008065 A, Fig. 1), said first electrode layer comprising a high-resistance material selected from the group consisting of a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21). It is noted that the embodiment of Fig. 2 of D1 has a three layer cathode. The additional layer with reference sign 4c also has a high resistance (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column

5, line 12). Therefore also all the materials considered for the layer 4c are disclosed as the high-resistance material (cf. Japanese Application JP 08 008065 A, column 5, lines 6-12).
Hence D1 discloses all the technical features of claim 5.

7.3 The subject-matter of independent claim 10 of the present application is not new in the sense of Article 33(2) PCT.
Document D1 discloses:
- an organic light-emitting device (cf. Japanese Application JP 08 008065 A, Fig. 2 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic layer and
- means for electrically isolating any conducting defect in the organic layer from an associated electrode (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4c: the electrode layer 4c is very thin and may be of a high-conductivity metal (e.g. 9 nm of Mg:Ag; cf. Japanese Application JP 08 008065 A, column 12, lines 39-50). It is used between the high-resistance layer 4a and the light-emissive organic layer 3o. According to the description of the present application page 20, last paragraph - page 21, line 2 the layer 4c therefore constitutes said means for electrically isolating any conducting defect).
Hence D1 discloses all the technical features of claim 10.

7.4 The subject-matter of independent claim 15 of the present application is not new in the sense of Article 33(2) PCT.
Document D1 discloses:
- an organic light-emitting device (cf. Japanese Application JP 08 008065 A, Fig. 2 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising
- a light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4) electrodes for

injecting charge carriers into the light-emissive organic layer,
- at least one of said first and second electrodes being opaque and comprising a plurality of layers (cf. Japanese Application JP 08 008065 A, Fig. 2, reference signs 4a, 4b and 4c) including:
- a thin first electrode layer comprising a low work function material adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4c and column 12, lines 39-42), and
- a second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic layer, said second electrode layer comprising a layer of a high-resistance material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material and a conductor material (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4a and column 4, lines 7-21).
Hence D1 discloses all the technical features of claim 15.

7.5 The subject-matter of independent claim 16 of the present application is not new in the sense of Article 33(2) PCT.
Document D1 discloses:
an organic light-emitting device (cf. Japanese Application JP 08 008065 A, Fig. 2 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic layer,
- at least one of said first and second electrodes comprising a plurality of layers (cf. Japanese Application JP 08 008065 A, Fig. 2, the electrode with reference sign 4 consists of layers 4a, 4b and 4c) including
- a thin first electrode layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4c) comprising a high work function material (cf. Japanese Application JP 08 008065 A, column 5, lines 9-12) adjacent the surface of the light emissive organic layer remote from the other of the first and second electrodes, and

- a second electrode layer adjacent the surface of the first electrode layer remote from the organic light-emissive material, said second electrode layer comprising a layer of a high-resistance material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4a and column 4, lines 7-21).
Hence D1 discloses all the technical features of claim 16.

7.6 The subject-matter of independent claim 18 of the present application is not new in the sense of Article 33(2) PCT.
Document D1 discloses:
an organic light-emitting device (cf. Japanese Application JP 08 008065 A, Fig. 2 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic layer,
- at least one of said first and second electrodes comprising a plurality of layers (cf. Japanese Application JP 08 008065 A, Fig. 2, reference signs 4a, 4b and 4c) including:
- a first electrode layer having a high resistance (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4a and column 4, lines 7-21), said first electrode layer having a thickness greater than the light emissive organic layer (cf. Japanese Application JP 08 008065 A, column 12, lines 34-50: the organic light-emitting layer is 65 nm thick and the high-resistance layer 4a is 135 nm thick), such that any intrinsic defects in the light-emissive organic layer are covered by the first electrode layer.
Hence D1 discloses all the technical features of claim 18.

7.7 The subject-matter of independent claim 27 of the present application cannot be considered as involving an inventive step (Article 33(3) PCT) for the following reasons.
Document D1, which is considered to represent the most relevant state of the art

for the subject-matter of independent claim 27, discloses
- an organic light-emissive device (cf. Japanese Application JP 08 008065 A, Fig. 1 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic region (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic region, at least one of said first and second electrodes comprising:
- a high-resistance first electrode layer (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4a and column 4, lines 7-13) adjacent the surface of the light-emissive organic region remote from the other of the first and second electrodes, said first electrode layer covering substantially the entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes and comprising a high-resistance material selected from the group consisting of a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21);
- and a conductive second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic region (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4b and column 4, lines 7-13)

from which the subject-matter of claim 27 differs in that in claim 27 it is specified that the conductive second electrode layer is patterned while in D1 the conductive second electrode layer is not patterned. It is however common in the art to form patterns on both electrodes in order to make display devices. Furthermore the skilled person would, in particular in the light of the teaching of D3, not pattern the high-resistance layer since it can provide good lateral isolation and it can protect the light-emissive layer (cf. D3, Fig. 8 (the high-resistance layer has the reference sign 7) and column 4, line 44 - column 5, line 22).

7.8 In case of independent claim 39 the same reasoning as in case of claim 27 applies, the difference between the two independent claims being that claim 39 defines the thickness of the high resistance layer as being greater than the

thickness of the organic light-emissive layer. This feature is however known from D1 (cf. also the comments on claim 18 above).
Hence the subject-matter of claim 39 of the present application cannot be considered as involving an inventive step (Article 33(3) PCT).

7.9 The subject-matter of independent claim 43 of the present application cannot be considered as involving an inventive step (Article 33(3) PCT) for the following reasons.
Document D1, which is considered to represent the most relevant state of the art for the subject-matter of independent claim 43, discloses
- an organic light-emissive device (cf. Japanese Application JP 08 008065 A, Fig. 2 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic region (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic region,
- at least one of said first and second electrodes comprising:
- a first electrode layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4c) comprising an insulator material (cf. Japanese Application JP 08 008065 A, column 4, line - 48 - column 5, line 12: e.g. BaO is an insulator material) adjacent the surface of the light-emissive organic region remote from the other of the first and second electrodes;
- a high-resistance second electrode layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4a and column 4, lines 7-13) adjacent the surface of the first electrode layer remote from the light-emissive organic region; and
- a conductive third electrode layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4b and column 4, lines 7-13) adjacent the surface of said second electrode layer remote from the first electrode layer; wherein
- said first and second electrode layers cover substantially the entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes (cf. Japanese Application JP 08 008065 A, Fig. 2); and
- said second electrode layer comprises a high-resistance material selected from the group consisting of a semiconductor material, a mixture of a semiconductor

material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21)

from which the subject-matter of claim 43 differs in that in claim 43 it is specified that the conductive third electrode layer is patterned while in D1 the conductive third electrode layer is not patterned. This is however considered an obvious feature (cf. the reasoning concerning claim 27 above).

Independent Method Claims of Invention i):

7.10 The subject-matter of independent claim 22 of the present application is not new in the sense of Article 33(2) PCT.

Document D1 discloses:

A method for improving the uniformity of current density of an organic light emitting device comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2),

the method comprising the step of

- forming one of the first and second electrodes from a plurality of electrode layers (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2, the electrode layers with reference signs 4a, 4b and 4c) including a first electrode layer having a high resistance (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2, layer 4a or 4c), said first electrode layer comprising a material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21 and column 4, line 48 - column 5, line 12).

Hence D1 discloses all the technical features of claim 22.

7.11 The subject-matter of independent claim 42 of the present application cannot be considered as involving an inventive step (Article 33(3) PCT) for the following reasons.

Document D1, which is considered to represent the most relevant state of the art for the subject-matter of independent claim 42, discloses:

- a method of forming an electrode of an organic light-emissive device comprising

a light-emissive organic region interposed between first and second electrodes for injecting charge carriers into the light-emissive organic region (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2),
- the method comprising forming one of the first and second electrodes by the steps of:
- first forming a high-resistance first electrode layer over substantially the entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes (cf. Japanese Application JP 08 008065 A, layer 4a in Fig. 1 or layer 4c in Fig. 2), said first electrode layer comprising a material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21 and column 4, line 48 - column 5, line 12); and
- then forming a conductive second electrode layer over the surface of said first electrode layer remote from the light-emissive organic region (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2, layer 4b and column 4, lines 7-13).

from which the subject-matter of claim 42 differs in that in claim 42 it is specified that the conductive second electrode layer is patterned while in D1 the conductive second electrode layer is not patterned. It is however common in the art to form patterns on both electrodes in order to make display devices. E.g. document D3 shows a patterned conductive electrode layer on top of a high-resistance layer (cf. D3, Fig. 8 (the high-resistance layer has the reference sign 7)).

Dependent Claims of Invention i):

7.12 Dependent claims 2-4, 6-8, 11-14, 17, 19-21, 28-31, 33, 34, 36-38, 40, 41, 44, 45, 47, 48, 50-58 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty (Article 33(2) PCT) and/or inventive step (Article 33(3) PCT), the reasons being as follows:
The features of the following dependent claims are known from D1:
Claim 2 (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2)
Claim 3 (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2 and column 4, lines 7-13)

Claim 4 (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21 and column 4, line 48 - column 5, line 12)
Claim 6 (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column 5, line 12)
Claim 7 (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21 and column 4, line 48 - column 5, line 12)
Claim 8 (cf. Japanese Application JP 08 008065 A, column 4, lines 34-38)
Claim 11 (cf. Japanese Application JP 08 008065 A, Fig. 2)
Claim 12 (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4c: the electrode layer 4c is very thin and may be of a high-conductivity metal (e.g. 9 nm of Mg:Ag; cf. Japanese Application JP 08 008065 A, column 12, lines 39-50)
Claim 13 (cf. Japanese Application JP 08 008065 A, Fig. 2, reference signs 4a and 4c and column 4, lines 14-21 and column 4, line 48 - column 5, line 12)
Claim 14 (cf. Japanese Application JP 08 008065 A, Fig. 2, reference signs 4a and 4c and column 4, lines 14-21 and column 5, lines 9-12)
Claim 17 (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4b and column 4, lines 34-38)
Claim 19 (cf. Japanese Application JP 08 008065 A, column 12, lines 47-50)
Claim 21 (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21)
Claim 28 (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2 and column 4, lines 14-21 and column 4, line 48 - column 5, line 12)
Claim 29 (cf. Japanese Application JP 08 008065 A, column 5, line 7)
Claim 30 (cf. Japanese Application JP 08 008065 A, column 5, line 7: Si in TiSi)
Claim 31 (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2 and column 4, lines 14-21 and column 4, line 48 - column 5, line 12)
Claim 33 (cf. Japanese Application JP 08 008065 A, column 5, line 7: Ti in TiSi)
Claim 34 (cf. Japanese Application JP 08 008065 A, column 4, lines 34-38)
Claim 37 (cf. Japanese Application JP 08 008065 A, column 5, line 10: gold has a work function greater than 4.5 eV)
Claim 38 (cf. Japanese Application JP 08 008065 A, column 5, line 10: gold)
Claim 41 (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21)
Claim 44 (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column 5, line 12: e.g. BaO is a dielectric material)
Claim 45 (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column 5, line 12: e.g. Ba is a low work function element)
Claim 47 (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21)

Claim 48 (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2 and column 4, lines 14-21 and column 4, line 48 - column 5, line 12)
Claim 50 (cf. Japanese Application JP 08 008065 A, column 5, line 7: Ti in TiSi)
Claim 51 (cf. Japanese Application JP 08 008065 A, column 4, lines 34-38)
Claim 53 (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column 5, line 2: the layer is proposed monoatomic)
Claim 54 (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column 5, line 2: the layer is proposed monoatomic)
Claim 56 (cf. Japanese Application JP 08 008065 A, column 5, lines 8-9: Li)
Claim 57 (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column 5, line 2: the layer is proposed monoatomic)
Claim 58 (cf. Japanese Application JP 08 008065 A, column 4, lines 34-38)

The claims defining the thickness of the high-resistance layer (Claims 20, 36, 40, 52, 55) cannot be considered as involving an inventive step (Article 33(3) PCT) as long as the material is not defined. The thickness defined would in the case of some materials render the device even non-functional.

7.13 Dependent claims 9, 32, 35, 46 and 49 concern the material selection for the high resistance electrode layer. The particular material choice is not anticipated nor rendered obvious by D1-D5. D6 discloses the particular materials (LiF-Al, CsF-Al). D6 does however neither anticipate nor suggest a high-resistance layer made of these materials. Thus the subject-matter of claims 9, 32, 35, 46 and 49 satisfies the criteria set forth in Article 33(2) and (3) PCT.

7.14 Dependent claim 24 concerns a light-emissive device with an electrode layer consisting of a plurality of sub-electrodes, wherein the sub-electrodes are connected via fusible links, just as in the case of independent claim 23 (Invention ii)). Hence the same reasoning applies (cf. point 8 below).

Further observation

7.15 It is noted that D4 (P-Document) discloses all the features of claims 15 and 18-22. It is also noted that D4 was published before the filing date of one of the two priority documents of the present application.

8 **Concerning Invention ii)**
(cf. Item IV of this communication)

8.1 The document D5 is regarded as being the closest prior art to the subject-matter of claim 23, and shows:
a light-emissive device comprising a layer of light-emissive material arranged between first and second electrode layers such that charge carriers can move between the first and second electrode layers and the light-emissive material (cf. D5, e.g. Fig. 1 and description thereof).

The subject-matter of claim 23 therefore differs from this known light-emissive device in that claim 23 specifies that:
at least the first electrode layer comprises a plurality of sub-electrodes, each sub-electrode being connected to each of any sub-electrodes directly surrounding it via a fusible link, each fusible link adapted to break when subjected to a current exceeding a specified value to electrically isolate the respective sub-electrode from the other sub-electrodes.

The subject-matter of claim 23 is therefore novel (Article 33(2) PCT).

The problem to be solved by the present invention may therefore be regarded as how to avoid excessive current caused by localised defects.
D5 addresses the same problem (cf. D5, column 1, lines 41-68). The solution provided in D5 is however different. In D5 the problem is solved by the use of a selenium layer and "utilizing the fact that the crystals in the selenium layer ... have a non-isotropic resistance in a certain crystallization direction, to thereby keep the burning of the EL device from occurring" (cf. D5, column 1, lines 63-68). The principle of the solution of D5 is further described at column 3, lines 25-39.
Claim 23 hence provides an alternative solution to the same problem. This alternative solution is neither disclosed nor suggested in D5, nor in any of the prior-art documents at hand. Hence, the solution to this problem proposed in claim 23 of the present application is considered as involving an inventive step (Article 33(3) PCT).

8.2 Claims 25 and 26 are dependent on claim 23 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

Re Item VII

Certain defects in the international application

9 Claim 59 contains a reference to the drawings. According to Rule 6.2(a) PCT, claims should not contain such references except where absolutely necessary, which is not the case here.

10 Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D1-D3 is not mentioned in the description, nor are these documents identified therein.

11 The independent claims are not in the two-part form in accordance with Rule 6.3(b) PCT, with those features known in combination from the prior art being placed in the preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).

12 The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

13 The expression "... the current density ... would be ... $60/\rho$ mA/cm^2." on page 17, lines 22-23 seems to contain a mistake. The resistivity ρ has the units Ωcm. Hence the current density is assigned the unit mA/Ωcm^3 in the above expression.

Re Item VIII

Certain observations on the international application

14 Although claims 1, 5, 10, 15, 16, 18, 27, 39 and 43 have been drafted as separate independent claims, they relate effectively to the same subject-matter and differ from each other only with regard to the definition of the subject-matter for which protection is sought or in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness. Moreover, lack of clarity of the claims as a whole arises, since the plurality of independent claims makes it difficult, if not impossible, to determine the matter for which protection is sought, and places an undue burden on others seeking to establish the extent of the protection.

Hence, claims 1, 5, 10, 15, 16, 18, 27, 39 and 43 do not meet the requirements of Article 6 PCT.

The same applies to the method claims 22 and 42.

15 Claims 6, 7, 8, 9, 55 and 58 inter alia refer to claim 1. In claim 1 a "first electrode layer", "the semiconductor material", "the insulator material" and "the conductor material" are however not defined. Thus a lack of clarity is caused (Article 6 PCT).

16 The relative terms "high" and "low" in "high-resistance", "high work function" and "low work function" used throughout the claims have no well-recognised meaning and leave the reader in doubt as to the meaning of the technical features to which they refer, thereby rendering the definition of the subject-matter of the claims unclear (Article 6 PCT).

17 In claim 3 the expression "... resistance .... not too high to cause a significant increase in the drive voltage..." renders the claim unclear (Article 6 PCT). It is vague what a "significant increase" is. Furthermore the relative term "...excessive currents ... " has no well defined meaning (Article 6 PCT).

18 The vague term "...anomalous currents ... " in claim 12 has no well defined meaning (Article 6 PCT).

9

PATENT COOPERATION TREATY

REC'D 13 MAR 2001
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PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference CDT 080 PCT	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/GB99/04150	International filing date *(day/month/year)* 15/12/1999	Priority date *(day/month/year)* 16/12/1998
International Patent Classification (IPC) or national classification and IPC H01L51/20		
Applicant CAMBRIDGE DISPLAY TECHNOLOGY LTD. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 19 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☒ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☒ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand 10/07/2000	Date of completion of this report 09.03.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Götz, A Telephone No. +49 89 2399 2498

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB99/04150

I. Basis of the report

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).)*:

   Description, pages:

   1-25 as published

   Claims, No.:

   1-59 as published

   Drawings, sheets:

   1/3-3/3 as published

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

II. Priority

1. ☐ This report has been established as if no priority had been claimed due to the failure to furnish within the prescribed time limit the requested:

   ☐ copy of the earlier application whose priority has been claimed.

   ☐ translation of the earlier application whose priority has been claimed.

2. ☐ This report has been established as if no priority had been claimed due to the fact that the priority claim has been found invalid.

   Thus for the purposes of this report, the international filing date indicated above is considered to be the relevant date.

3. Additional observations, if necessary:
   see separate sheet

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

   ☐ restricted the claims.

   ☐ paid additional fees.

   ☒ paid additional fees under protest.

   ☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☒ not complied with for the following reasons:
   see separate sh et

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   ☒ all parts.

   ☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	9, 23-58
	No:	Claims	1-8, 10-22, 59
Inventive step (IS)	Yes:	Claims	9, 23-26, 32, 35, 46, 49
	No:	Claims	27-31, 33, 34, 36-45, 47, 48, 50-58
Industrial applicability (IA)	Yes:	Claims	1-59
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

1 Reference is made to the following documents:

D1: PATENT ABSTRACTS OF JAPAN vol. 1996, no. 05, 31 May 1996 (1996-05-31) -& JP 08 008065 A (TOPPAN PRINTING CO LTD), 12 January 1996 (1996-01-12) -& English language translation
D2: US-A-5 739 545 (GUHA SUPRATIK ET AL) 14 April 1998 (1998-04-14)
D3: US-A-4 634 934 (TOHDA ET AL) 6 January 1987 (1987-01-06)
D4: EP-A-0 903 964 (EASTMAN KODAK CO) 24 March 1999 (1999-03-24)
D5: US-A-4 647 813 (KITABAYASHI MOTOI ET AL) 3 March 1987 (1987-03-03)
D6: JABBOUR G E ET AL: 'ALUMINUM BASED CATHODE STRUCTURE FOR ENHANCED ELECTRON INJECTION IN ELECTROLUMINESCENT ORGANIC DEVICES' APPLIED PHYSICS LETTERS, US, AMERICAN INSTITUTE OF PHYSICS. NEW YORK, vol. 73, no. 9, 31 August 1998 (1998-08-31), pages 1185-1187, XP000781203 ISSN: 0003-6951

The documents D1 and D3 were not cited in the international search report.

Re Item II
Priority

2 It is noted that part of the present application (e.g. Fig. 6) was not disclosed in none of the two priority documents.

Re Item IV
Lack of unity of invention

3 Independent claims 1, 5, 10, 15, 16, 18, 27, 39 and 43 are directed to organic light-emitting devices including means for limiting the current flow through any conductive defect in the light-emissive organic layer. The problem to be solved is to reduce the leakage current through conductive defects in the organic light-emissive layer.

Independent claims 22 and 42 are directed to a fabrication method of such a device.

4 Independent claim 23 is directed to a light-emissive device with an electrode layer consisting of a plurality of sub-electrodes, wherein the sub-electrodes are connected via fusible links. The fusible links permit to electrically isolate sub-electrodes by blowing the fusible link. The device is not specified to be organic.

5 As a consequence there are the following independent inventions not linked by a common inventive concept:
i) The organic light-emitting device and fabrication method thereof according to independent claims 1, 5, 10, 15, 16, 18, 22, 27, 39, 42 and 43 and the claims depending on these independent claims.
ii) The light-emissive device according to independent claim 23 and the claims depending on claim 23.

6 The independent inventions i) and ii) provide different solutions for the problem of avoiding excessive current.

<u>Re Item V</u>

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

7 **Concerning Invention i)**
(cf. Item IV of this communication)

Independent Device Claims of Invention i):

7.1 The subject-matter of independent claim 1 of the present application is not new in the sense of Article 33(2) PCT.
Document D1 discloses:
- an organic light-emitting device (cf. Japanese Application JP 08 008065 A, Fig. 1 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic layer and
- means for limiting the current flow through any conductive defect in said

light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4a and column 4, lines 7-13: the first cathode layer is described as a layer of material of low conductivity which is covered with a layer of high conductivity. The layer of low conductivity limits the current through any conductive defect in the light-emissive organic layer).
Hence D1 discloses all the technical features of claim 1.

It is pointed out that D2 discloses all the features of claim 1, too. The relevant passage is D2, column 3, lines 30-34, from which it is clear that the light-emissive organic device has means for limiting the current flow.

7.2 The subject-matter of independent claim 5 of the present application is not new in the sense of Article 33(2) PCT.
Document D1 discloses:
- an organic light-emitting device (cf. Japanese Application JP 08 008065 A, Fig. 1 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic layer, at least one of said first and second electrodes comprising a plurality of layers (cf. Japanese Application JP 08 008065 A, Fig. 1, the electrode with reference sign 4 consists of layers 4a and 4b) including a first electrode layer (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4a) having a high resistance (cf. Japanese Application JP 08 008065 A, column 4, lines 7-13) adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes (cf. Japanese Application JP 08 008065 A, Fig. 1), said first electrode layer comprising a high-resistance material selected from the group consisting of a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21). It is noted that the embodiment of Fig. 2 of D1 has a three layer cathode. The additional layer with reference sign 4c also has a high resistance (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column

5, line 12). Therefore also all the materials considered for the layer 4c are disclosed as the high-resistance material (cf. Japanese Application JP 08 008065 A, column 5, lines 6-12).
Hence D1 discloses all the technical features of claim 5.

7.3 The subject-matter of independent claim 10 of the present application is not new in the sense of Article 33(2) PCT.
Document D1 discloses:
- an organic light-emitting device (cf. Japanese Application JP 08 008065 A, Fig. 2 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic layer and
- means for electrically isolating any conducting defect in the organic layer from an associated electrode (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4c: the electrode layer 4c is very thin and may be of a high-conductivity metal (e.g. 9 nm of Mg:Ag; cf. Japanese Application JP 08 008065 A, column 12, lines 39-50). It is used between the high-resistance layer 4a and the light-emissive organic layer 3o. According to the description of the present application page 20, last paragraph - page 21, line 2 the layer 4c therefore constitutes said means for electrically isolating any conducting defect).
Hence D1 discloses all the technical features of claim 10.

7.4 The subject-matter of independent claim 15 of the present application is not new in the sense of Article 33(2) PCT.
Document D1 discloses:
- an organic light-emitting device (cf. Japanese Application JP 08 008065 A, Fig. 2 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising
- a light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4) electrodes for

injecting charge carriers into the light-emissive organic layer,
- at least one of said first and second electrodes being opaque and comprising a plurality of layers (cf. Japanese Application JP 08 008065 A, Fig. 2, reference signs 4a, 4b and 4c) including:
- a thin first electrode layer comprising a low work function material adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4c and column 12, lines 39-42), and
- a second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic layer, said second electrode layer comprising a layer of a high-resistance material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material and a conductor material (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4a and column 4, lines 7-21).
Hence D1 discloses all the technical features of claim 15.

7.5 The subject-matter of independent claim 16 of the present application is not new in the sense of Article 33(2) PCT.
Document D1 discloses:
an organic light-emitting device (cf. Japanese Application JP 08 008065 A, Fig. 2 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic layer,
- at least one of said first and second electrodes comprising a plurality of layers (cf. Japanese Application JP 08 008065 A, Fig. 2, the electrode with reference sign 4 consists of layers 4a, 4b and 4c) including
- a thin first electrode layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4c) comprising a high work function material (cf. Japanese Application JP 08 008065 A, column 5, lines 9-12) adjacent the surface of the light emissive organic layer remote from the other of the first and second electrodes, and

- a second electrode layer adjacent the surface of the first electrode layer remote from the organic light-emissive material, said second electrode layer comprising a layer of a high-resistance material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4a and column 4, lines 7-21). Hence D1 discloses all the technical features of claim 16.

7.6 The subject-matter of independent claim 18 of the present application is not new in the sense of Article 33(2) PCT.
Document D1 discloses:
an organic light-emitting device (cf. Japanese Application JP 08 008065 A, Fig. 2 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic layer,
- at least one of said first and second electrodes comprising a plurality of layers (cf. Japanese Application JP 08 008065 A, Fig. 2, reference signs 4a, 4b and 4c) including:
- a first electrode layer having a high resistance (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4a and column 4, lines 7-21), said first electrode layer having a thickness greater than the light emissive organic layer (cf. Japanese Application JP 08 008065 A, column 12, lines 34-50: the organic light-emitting layer is 65 nm thick and the high-resistance layer 4a is 135 nm thick), such that any intrinsic defects in the light-emissive organic layer are covered by the first electrode layer.
Hence D1 discloses all the technical features of claim 18.

7.7 The subject-matter of independent claim 27 of the present application cannot be considered as involving an inventive step (Article 33(3) PCT) for the following reasons.
Document D1, which is considered to represent the most relevant state of the art

for the subject-matter of independent claim 27, discloses

- an organic light-emissive device (cf. Japanese Application JP 08 008065 A, Fig. 1 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic region (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic region, at least one of said first and second electrodes comprising:
- a high-resistance first electrode layer (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4a and column 4, lines 7-13) adjacent the surface of the light-emissive organic region remote from the other of the first and second electrodes, said first electrode layer covering substantially the entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes and comprising a high-resistance material selected from the group consisting of a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21);
- and a conductive second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic region (cf. Japanese Application JP 08 008065 A, Fig. 1, reference sign 4b and column 4, lines 7-13)

from which the subject-matter of claim 27 differs in that in claim 27 it is specified that the conductive second electrode layer is patterned while in D1 the conductive second electrode layer is not patterned. It is however common in the art to form patterns on both electrodes in order to make display devices. Furthermore the skilled person would, in particular in the light of the teaching of D3, not pattern the high-resistance layer since it can provide good lateral isolation and it can protect the light-emissive layer (cf. D3, Fig. 8 (the high-resistance layer has the reference sign 7) and column 4, line 44 - column 5, line 22).

7.8 In case of independent claim 39 the same reasoning as in case of claim 27 applies, the difference between the two independent claims being that claim 39 defines the thickness of the high resistance layer as being greater than the

thickness of the organic light-emissive layer. This feature is however known from D1 (cf. also the comments on claim 18 above).
Hence the subject-matter of claim 39 of the present application cannot be considered as involving an inventive step (Article 33(3) PCT).

7.9 The subject-matter of independent claim 43 of the present application cannot be considered as involving an inventive step (Article 33(3) PCT) for the following reasons.
Document D1, which is considered to represent the most relevant state of the art for the subject-matter of independent claim 43, discloses
- an organic light-emissive device (cf. Japanese Application JP 08 008065 A, Fig. 2 and column 12, lines 34-38 and English-language abstract, paragraph "CONSTITUTION") comprising:
- a light-emissive organic region (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 3o and column 12, lines 34-38) interposed between first (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 2) and second (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4) electrodes for injecting charge carriers into the light-emissive organic region,
- at least one of said first and second electrodes comprising:
- a first electrode layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4c) comprising an insulator material (cf. Japanese Application JP 08 008065 A, column 4, line - 48 - column 5, line 12: e.g. BaO is an insulator material) adjacent the surface of the light-emissive organic region remote from the other of the first and second electrodes;
- a high-resistance second electrode layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4a and column 4, lines 7-13) adjacent the surface of the first electrode layer remote from the light-emissive organic region; and
- a conductive third electrode layer (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4b and column 4, lines 7-13) adjacent the surface of said second electrode layer remote from the first electrode layer; wherein
- said first and second electrode layers cover substantially the entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes (cf. Japanese Application JP 08 008065 A, Fig. 2); and
- said second electrode layer comprises a high-resistance material selected from the group consisting of a semiconductor material, a mixture of a semiconductor

material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21)

from which the subject-matter of claim 43 differs in that in claim 43 it is specified that the conductive third electrode layer is patterned while in D1 the conductive third electrode layer is not patterned. This is however considered an obvious feature (cf. the reasoning concerning claim 27 above).

Independent Method Claims of Invention i):

7.10 The subject-matter of independent claim 22 of the present application is not new in the sense of Article 33(2) PCT.

Document D1 discloses:

A method for improving the uniformity of current density of an organic light emitting device comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2),

the method comprising the step of

- forming one of the first and second electrodes from a plurality of electrode layers (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2, the electrode layers with reference signs 4a, 4b and 4c) including a first electrode layer having a high resistance (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2, layer 4a or 4c), said first electrode layer comprising a material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21 and column 4, line 48 - column 5, line 12).

Hence D1 discloses all the technical features of claim 22.

7.11 The subject-matter of independent claim 42 of the present application cannot be considered as involving an inventive step (Article 33(3) PCT) for the following reasons.

Document D1, which is considered to represent the most relevant state of the art for the subject-matter of independent claim 42, discloses:

- a method of forming an electrode of an organic light-emissive device comprising

a light-emissive organic region interposed between first and second electrodes for injecting charge carriers into the light-emissive organic region (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2),
- the method comprising forming one of the first and second electrodes by the steps of:
- first forming a high-resistance first electrode layer over substantially the entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes (cf. Japanese Application JP 08 008065 A, layer 4a in Fig. 1 or layer 4c in Fig. 2), said first electrode layer comprising a material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21 and column 4, line 48 - column 5, line 12); and
- then forming a conductive second electrode layer over the surface of said first electrode layer remote from the light-emissive organic region (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2, layer 4b and column 4, lines 7-13).

from which the subject-matter of claim 42 differs in that in claim 42 it is specified that the conductive second electrode layer is patterned while in D1 the conductive second electrode layer is not patterned. It is however common in the art to form patterns on both electrodes in order to make display devices. E.g. document D3 shows a patterned conductive electrode layer on top of a high-resistance layer (cf. D3, Fig. 8 (the high-resistance layer has the reference sign 7)).

Dependent Claims of Invention i):

7.12 Dependent claims 2-4, 6-8, 11-14, 17, 19-21, 28-31, 33, 34, 36-38, 40, 41, 44, 45, 47, 48, 50-58 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty (Article 33(2) PCT) and/or inventive step (Article 33(3) PCT), the reasons being as follows:
The features of the following dependent claims are known from D1:
Claim 2 (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2)
Claim 3 (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2 and column 4, lines 7-13)

Claim 4 (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21 and column 4, line 48 - column 5, line 12)
Claim 6 (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column 5, line 12)
Claim 7 (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21 and column 4, line 48 - column 5, line 12)
Claim 8 (cf. Japanese Application JP 08 008065 A, column 4, lines 34-38)
Claim 11 (cf. Japanese Application JP 08 008065 A, Fig. 2)
Claim 12 (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4c: the electrode layer 4c is very thin and may be of a high-conductivity metal (e.g. 9 nm of Mg:Ag; cf. Japanese Application JP 08 008065 A, column 12, lines 39-50)
Claim 13 (cf. Japanese Application JP 08 008065 A, Fig. 2, reference signs 4a and 4c and column 4, lines 14-21 and column 4, line 48 - column 5, line 12)
Claim 14 (cf. Japanese Application JP 08 008065 A, Fig. 2, reference signs 4a and 4c and column 4, lines 14-21 and column 5, lines 9-12)
Claim 17 (cf. Japanese Application JP 08 008065 A, Fig. 2, reference sign 4b and column 4, lines 34-38)
Claim 19 (cf. Japanese Application JP 08 008065 A, column 12, lines 47-50)
Claim 21 (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21)
Claim 28 (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2 and column 4, lines 14-21 and column 4, line 48 - column 5, line 12)
Claim 29 (cf. Japanese Application JP 08 008065 A, column 5, line 7)
Claim 30 (cf. Japanese Application JP 08 008065 A, column 5, line 7: Si in TiSi)
Claim 31 (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2 and column 4, lines 14-21 and column 4, line 48 - column 5, line 12)
Claim 33 (cf. Japanese Application JP 08 008065 A, column 5, line 7: Ti in TiSi)
Claim 34 (cf. Japanese Application JP 08 008065 A, column 4, lines 34-38)
Claim 37 (cf. Japanese Application JP 08 008065 A, column 5, line 10: gold has a work function greater than 4.5 eV)
Claim 38 (cf. Japanese Application JP 08 008065 A, column 5, line 10: gold)
Claim 41 (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21)
Claim 44 (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column 5, line 12: e.g. BaO is a dielectric material)
Claim 45 (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column 5, line 12: e.g. Ba is a low work function element)
Claim 47 (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21)

Claim 48 (cf. Japanese Application JP 08 008065 A, Figs. 1 and 2 and column 4, lines 14-21 and column 4, line 48 - column 5, line 12)
Claim 50 (cf. Japanese Application JP 08 008065 A, column 5, line 7: Ti in TiSi)
Claim 51 (cf. Japanese Application JP 08 008065 A, column 4, lines 34-38)
Claim 53 (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column 5, line 2: the layer is proposed monoatomic)
Claim 54 (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column 5, line 2: the layer is proposed monoatomic)
Claim 56 (cf. Japanese Application JP 08 008065 A, column 5, lines 8-9: Li)
Claim 57 (cf. Japanese Application JP 08 008065 A, column 4, line 48 - column 5, line 2: the layer is proposed monoatomic)
Claim 58 (cf. Japanese Application JP 08 008065 A, column 4, lines 34-38)

The claims defining the thickness of the high-resistance layer (Claims 20, 36, 40, 52, 55) cannot be considered as involving an inventive step (Article 33(3) PCT) as long as the material is not defined. The thickness defined would in the case of some materials render the device even non-functional.

7.13 Dependent claims 9, 32, 35, 46 and 49 concern the material selection for the high resistance electrode layer. The particular material choice is not anticipated nor rendered obvious by D1-D5. D6 discloses the particular materials (LiF-Al, CsF-Al). D6 does however neither anticipate nor suggest a high-resistance layer made of these materials. Thus the subject-matter of claims 9, 32, 35, 46 and 49 satisfies the criteria set forth in Article 33(2) and (3) PCT.

7.14 Dependent claim 24 concerns a light-emissive device with an electrode layer consisting of a plurality of sub-electrodes, wherein the sub-electrodes are connected via fusible links, just as in the case of independent claim 23 (Invention ii)). Hence the same reasoning applies (cf. point 8 below).

Further observation

7.15 It is noted that D4 (P-Document) discloses all the features of claims 15 and 18-22. It is also noted that D4 was published before the filing date of one of the two priority documents of the present application.

8 Conc rning Invention ii)
(cf. Item IV of this communication)

8.1 The document D5 is regarded as being the closest prior art to the subject-matter of claim 23, and shows:
a light-emissive device comprising a layer of light-emissive material arranged between first and second electrode layers such that charge carriers can move between the first and second electrode layers and the light-emissive material (cf. D5, e.g. Fig. 1 and description thereof).

The subject-matter of claim 23 therefore differs from this known light-emissive device in that claim 23 specifies that:
at least the first electrode layer comprises a plurality of sub-electrodes, each sub-electrode being connected to each of any sub-electrodes directly surrounding it via a fusible link, each fusible link adapted to break when subjected to a current exceeding a specified value to electrically isolate the respective sub-electrode from the other sub-electrodes.

The subject-matter of claim 23 is therefore novel (Article 33(2) PCT).

The problem to be solved by the present invention may therefore be regarded as how to avoid excessive current caused by localised defects.
D5 addresses the same problem (cf. D5, column 1, lines 41-68). The solution provided in D5 is however different. In D5 the problem is solved by the use of a selenium layer and "utilizing the fact that the crystals in the selenium layer ... have a non-isotropic resistance in a certain crystallization direction, to thereby keep the burning of the EL device from occurring" (cf. D5, column 1, lines 63-68). The principle of the solution of D5 is further described at column 3, lines 25-39.
Claim 23 hence provides an alternative solution to the same problem. This alternative solution is neither disclosed nor suggested in D5, nor in any of the prior-art documents at hand. Hence, the solution to this problem proposed in claim 23 of the present application is considered as involving an inventive step (Article 33(3) PCT).

8.2 Claims 25 and 26 are dependent on claim 23 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

Re Item VII

Certain defects in the international application

9 Claim 59 contains a reference to the drawings. According to Rule 6.2(a) PCT, claims should not contain such references except where absolutely necessary, which is not the case here.

10 Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D1-D3 is not mentioned in the description, nor are these documents identified therein.

11 The independent claims are not in the two-part form in accordance with Rule 6.3(b) PCT, with those features known in combination from the prior art being placed in the preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).

12 The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

13 The expression "... the current density ... would be ... $60/\rho$ mA/cm^2." on page 17, lines 22-23 seems to contain a mistake. The resistivity ρ has the units Ωcm. Hence the current density is assigned the unit $mA/\Omega cm^3$ in the above expression.

Re Item VIII

Certain observations on the international application

14 Although claims 1, 5, 10, 15, 16, 18, 27, 39 and 43 have been drafted as separate independent claims, they relate effectively to the same subject-matter and differ from each other only with regard to the definition of the subject-matter for which protection is sought or in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness. Moreover, lack of clarity of the claims as a whole arises, since the plurality of independent claims makes it difficult, if not impossible, to determine the matter for which protection is sought, and places an undue burden on others seeking to establish the extent of the protection.

Hence, claims 1, 5, 10, 15, 16, 18, 27, 39 and 43 do not meet the requirements of Article 6 PCT.

The same applies to the method claims 22 and 42.

15 Claims 6, 7, 8, 9, 55 and 58 inter alia refer to claim 1. In claim 1 a "first electrode layer", "the semiconductor material", "the insulator material" and "the conductor material" are however not defined. Thus a lack of clarity is caused (Article 6 PCT).

16 The relative terms "high" and "low" in "high-resistance", "high work function" and "low work function" used throughout the claims have no well-recognised meaning and leave the reader in doubt as to the meaning of the technical features to which they refer, thereby rendering the definition of the subject-matter of the claims unclear (Article 6 PCT).

17 In claim 3 the expression "... resistance .... not too high to cause a significant increase in the drive voltage..." renders the claim unclear (Article 6 PCT). It is vague what a "significant increase" is. Furthermore the relative term "...excessive currents ... " has no well defined meaning (Article 6 PCT).

18 The vague term "...anomalous currents ... " in claim 12 has no well defined meaning (Article 6 PCT).

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

To:
CAMBRIDGE DISPLAY TECHNOLOGY LTD,
Greenwich House
Attn. HARTWELL, Ian Peter
Madingley Rise
Madingley Road
Cambridge CB3 OHJ
UNITED KINGDOM

Date of mailing (*day/month/year*) 31/03/2000	
Applicant's or agent's file reference 80	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/GB 99/ 04150	International filing date (*day/month/year*) 15/12/1999
Applicant CAMBRIDGE DISPLAY TECHNOLOGY LTD. et al.	

1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Fascimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Trudy Thoen-de Jong

Form PCT/ISA/220 (July 1998)

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international pbulication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped), whether

(i) the claim is unchanged;

(ii) the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."

2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."

3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."

4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international appplication is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

ORGANIC LIGHT-EMITTING DEVICES

Field of the Invention

This invention relates to organic light-emitting devices (OLEDs) and a method for improving the uniformity of current density of OLEDs having a light-emissive organic layer containing intrinsic defects.

The present invention also relates to organic light-emissive devices having patterned electrodes.

Background to the Invention

Organic light-emitting devices such as described in US Patent No. 5,247,190 or in US Patent No. 4,539,507, the contents of which are incorporated herein by reference, have great potential for use in various display applications. According to one method, an OLED is fabricated by coating a glass or plastic substrate with a transparent first electrode (anode) such as indium tin oxide (ITO). At least one layer of a thin film of an electroluminescent organic material is then deposited prior to a final layer which is a film of a second electrode (cathode) which is typically a metal or alloy.

In many practical applications, the layer of electroluminescent organic material has a thickness of the order of 100nm in order to ensure a practical operating voltage. It is typically deposited on the first electrode by a spin-coating technique. If the organic material is contaminated with particles having a size of the order of the thickness of the organic layer, not only will these particles themselves give rise to defects in the resulting organic layer, their presence disrupts the movement of the fluid organic material over the surface of the first electrode layer leading to variations in the thickness of the resulting organic layer about the particle, and in the worst case leading to the formation of holes in the organic layer through which the underlying layer (electrode layer) is exposed.

Defects in the organic layer can also be caused by, for example, inherently poor film-forming properties of the organic material, or by physical damage to the organic layer after deposition.

A typical defect site is shown in Figure 3. The electroluminescent organic layer 106 has been deposited by spin coating on a glass substrate 102 coated with an indium tin oxide (ITO) anode layer. The existence of a large particle 107 has led to a defect site 109 comprising the particle 107 itself and a pinhole 111. A cathode layer 110 is formed over the electroluminescent organic layer 106.

Localised defects of the kind shown in Figure 3 can manifest themselves during device operation as a current anomaly (short) where a large proportion of the current becomes localised in the area of the defect. This leads, inter alia, to problems of device reproducibility and is a particular problem in dot matrix devices since it provides alternative current paths that lead to the wrong pixels being lit.

In order to prevent these kind of defects, the deposition of the organic layer is typically carried out in a clean room with a view to preventing contamination and typically involves filtering the organic material prior to spinning to remove large particles therefrom. However, a typical clean room has particle size levels specified down to 300nm and the organic material is only typically filtered to about 450nm, since the elimination of particles having smaller sizes requires great expense.

The light-emissive organic material will therefore often still be contaminated with particles having a size of the order of the thickness of the organic layer to be deposited, which will, as mentioned above, lead to defects in the resulting organic layer. Furthermore, even if the contamination by such large particles could be completely eliminated, defects can still arise during the manufacturing process as a result, for example, of inherently poor film-forming properties of the organic material itself, or due to physical damage inadvertently inflicted on the organic layer after deposition.

One known technique of removing the defect particles after production of the device is by passing a very high current through the device to "burn-out" the defect particles by vaporizing them. However, this technique is not applicable to all defect particles and cannot be used to resolve the problem of large shorts. Moreover, it does not necessarily deal with problems that may manifest themselves in the lifetime of the device.It is therefore an aim of the present invention to reduce the problem of current anomalies in an organic light-emitting device.

In organic light-emissive devices (OLED's) such as those described in our earlier US-A-5, 247, 190 or in Van Slyke et al.'s US-A-4, 539, 507, light emission from the at least one organic layer occurs only where the cathode and the anode overlap and therefore pixelation and patterning is achieved simply by patterning the electrodes. High resolution is readily achieved and is principally limited only by the overlap area of the cathode and the anode and thus by the size of the cathode and the anode. Dot-matrix displays are commonly fabricated by arranging the cathode and the anode as perpendicular arrays of rows and columns, with the at least one organic layer being disposed therebetween.

Low resolution dot-matrix displays can, for example, be fabricated by coating at least one organic electroluminescent layer onto a substrate having thereon an array of indium-tin oxide (ITO) lines which act as an anode. A cathode comprising an array of lines perpendicular to those of the anode is provided on the other side of the at least one organic layer. These cathode lines may, for example, be lines of aluminium or an aluminium-based alloy which can be evaporated or sputtered through a physical shadow mask. However, shadow masking may not be desirable for various reasons. In particular, there are significant constraints on the use of shadow masks when displays of large area and/or high resolution are required. In order to produce such electrode line arrays and other patterns of large area and/or high resolution one would normally have to use various forms of lithography.

In order to fabricate efficient and stable OLED's with the desired electrical and light output characteristics great care must normally be taken in the design and construction of the interfaces between any organic layer and the electrodes. The particular importance of these interfaces is due to the fact that charge carriers

should be injected efficiently from the electrodes into the at least one organic layer.

Maintaining the desired electrical and light output characteristic of the pixels in an OLED display when lithographic processes are used to fabricate the electrode patterns, in particular where those patterns are on top of the at least one organic layer, is not trivial owing to the risk of the lithographic processes modifying and potentially damaging the organic layer/electrode interfaces and the vicinity. Such damage during lithography may originate from the photoresist, the developers, the etching processes (both dry and wet, negative and positive techniques and etch and lift-off) or the solvents used. It should be mentioned here that conjugated polymers are often deposited from and are generally soluble in organic solvents.

Plasma etching/ashing is very often used in lithography to remove the photoresist or residual photoresist which may not have been washed off the developer. Organic electroluminescent and charge transporting materials would normally be damaged, modified and/or etched very rapidly in such dry etching/ashing processes if directly exposed to the plasma.

One method of protecting the organic electroluminescent and charge transporting materials from the effects of the electrode patterning processes is disclosed in WO97/42666 in which a thin barrier layer composed of a dielectric material is interposed between the conductive electrode layer and the layer of light-emissive organic material.

The inventors of the present invention have identified the requirement for an improved construction which allows for the use of various lithographic processes to form the electrode on top of at least one organic layer without significantly changing the electrical and light output characteristics of the display, and which meets todays demands for increased efficiency, reliability and durability. It is therefore another aim of the present invention to provide a device which meets these requirements.

Summary of the Invention

According to a first aspect of the present invention there is provided an organic light-emitting device comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer and means for limiting the current flow through any conductive defect in said light-emissive organic layer. In contrast to the "burn out" technique referred to above, the incorporation into the device of means for limiting the current flow through any conductive defect in the light-emissive layer prevents any current anomalies arising during the lifetime of the device from rising to such a level as to significantly affect device operation in the manner described above.

Preferably the means are incorporated into at least one of said first and second electrodes of the device. In particular, the electrode may comprise a plurality of layers including a first electrode layer adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes and having a resistance selected such that it is not too high to cause a significant increase in the drive voltage of the device, yet high enough to prevent excessive currents at any conductive defect in said light-emissive organic layer.

According to one embodiment of the invention, the first electrode layer may comprise a high-resistance material selected from the group consisting of a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material. The use of a layer of the above-mentioned mixtures of materials as the high resistance electrode layer has the advantage that the resistance of the high resistance electrode layer can be easily adjusted to the desired value by simply adjusting the relative proportions of the components of the mixture accordingly.

In the case of a cathode, the first electrode layer preferably comprises at least one material having a low work function, preferably less than 3.7 eV, and further preferably less than 3.2 eV, to improve the electron-injecting performance of the cathode.

According to a second aspect of the present invention, there is provided an organic light-emitting device comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer and means for electrically isolating any conducting defect in the organic layer from an associated electrode. Any current anomalies arising during the lifetime of the device according to this aspect of the invention are short-lived – the conducting defect in the organic layer giving rise to the current anomaly is rapidly isolated from the associated electrode by means incorporated in the device.

These means are preferably incorporated into at least one of said first and second electrodes, which may comprise a plurality of layers including a thin first electrode layer adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes, the dimensions and material properties of said thin first electrode layer being chosen such that, adjacent a conducting defect in said organic layer, said layer will vapourise when subject to an anomalous current resulting from said conducting defect.

According to one embodiment of the invention, the electrode is opaque and comprises a plurality of layers including a thin first electrode layer comprising a low work function material adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes, and a second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic layer, said second electrode layer comprising a layer of a high-resistance material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material and a conductor material.

Alternatively, the electrode may have a first electrode layer comprising a plurality of sub-electrodes, each sub-electrode being connected to each of any sub-electrodes directly surrounding it via a fusible link, each fusible link adapted to break when subject to a current exceeding a specified value to electrically isolate the respective sub-electrode from the other sub-electrodes.

The thin first electrode layer in this second aspect of the present invention preferably has a thickness in the range of 0.5 to 10 nm, and is further preferably 5nm or less.

According to a third aspect of the present invention, there is provided an organic light-emitting device comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer, at least one of said first and second electrodes comprising a plurality of layers including a first electrode layer having a high resistance, said first electrode layer having a thickness greater than the light-emissive organic layer, such that any intrinsic defects in the light-emissive organic layer are covered by the first electrode layer.

According to one embodiment, the first electrode layer is disposed adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes.

By making the thickness of the high resistance first electrode layer greater than that of the light-emissive organic layer, any pinhole defects in the light-emissive organic layer are completely filled making it possible to further ensure that there are no areas of the light-emissive organic layer left exposed to make direct contact with an overlying conductive layer.

The high resistance layer in this third aspect of the invention preferably comprises a semiconductor material, a mixture of a semiconductor material with a conductor material, a mixture of a semiconductor material with an insulator material or a mixture of a conductor material with an insulator material.

According to a fourth aspect of the present invention, there is provided a method for improving the uniformity of current density of an organic light-emitting device comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer, the method comprising the step of forming one of the first and second electrodes from

a plurality of layers including a first electrode layer having a high resistance comprising a semiconductor material, a mixture of an insulator material with a semiconductor material, a mixture of an insulator material with a conductor material, or a mixture of a semiconductor material with a conductor material.

In each of the above aspects of the invention, the high-resistance electrode layer is preferably capped with a layer of a conductor material such as a layer of aluminium.

The resistance of the high resistance electrode layer in the first to fourth aspects of the present invention is preferably selected such that it is not too high to cause a significant increase in the drive voltage (since this will reduce the power efficiency of the device) but is high enough to prevent excessive currents at defect sites. Typically for an electrode layer of thickness lying in the range of 100-10000nm, the resistivity lies in the range 1 to 10^5 Ωcm.

Suitable semiconductor materials for use in the above aspects of the present invention include, for example, Ge, Si, α-Sn, Se, ZnSe, ZnS, GaAs, GaP, CdS, CdSe, MnS, MnSe, PbS, ZnO, SnO, TiO_2, MnO_2 and SiC.

Suitable insulator materials for use in the above aspects of the present invention include, for example, insulating oxides, nitrides and fluorides such as Al_2O_3, SiO_2, LiO, AlN, SiN, LiF and CsF. Suitable conductor materials for use in the present invention include, for example, metals such as Al and Ag.

Suitable low work function materials for use in the present invention include, for example, Ca, Li, Yb, LiF, CsF and LiO.

The use of the cathode to combat the undesirable effects of intrinsic defects in the light-emissive organic layer is particularly advantageous when the cathode is deposited in a vacuum because of the ability to keep particulate levels extremely low.

According to a sixth aspect of the present invention, there is provided a light-emissive device comprising a layer of light-emissive material arranged between first and second electrode layers such that charge carriers can move between the first and second electrode layers and the light-emissive material, wherein at least the first electrode layer comprises a plurality of sub-electrodes, each sub-electrode being connected to each of any sub-electrodes directly surrounding it via a fusible link, each fusible link adapted to break when subject to a current exceeding a specified value to electrically isolate the respective sub-electrode from the other sub-electrodes.

In a preferred embodiment of the sixth aspect of the present invention, the plurality of sub-electrodes are arranged to create an ordered array of parallel rows and columns, and each of the sub-electrodes is connected via a fusible link to each of any sub-electrodes directly adjacent to it in the same column and row.

The size and spacing of the sub-electrodes is preferably selected such that, during operation of the device, the light emitted by the light-emissive device appears to the human eye to be continuous in intensity across the whole area of light emission.

According to a seventh aspect of the present invention there is provided an organic light-emissive device comprising a light-emissive organic region interposed between first and second electrodes for injecting charge carriers into the light-emissive organic region, at least one of said first and second electrodes comprising: a high-resistance first electrode layer adjacent the surface of the light-emissive organic region remote from the other of the first and second electrodes, said first electrode layer covering substantially the entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes and comprising a high-resistance material selected from the group consisting of a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material; and a patterned conductive second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic region.

In the seventh aspect of the present invention, the first electrode layer is, as described above, formed over substantially the entire surface of the light-emissive organic region. In other words, the first electrode layer is formed over at least that area of the surface of the light-emissive organic region corresponding to the area occupied by the second electrode layer as defined by the laterally outermost edges of the patterned second electrode layer.

The term "patterned electrode layer" refers to a plurality of electrode elements which are only connected via the underlying high resistance first electrode layer. The patterned electrode layer preferably comprises an ordered array of separate elements such as a series of parallel rows or columns which are only connected via the underlying high resistance first electrode layer.

The resistance of the high resistance first electrode layer in this seventh aspect of the present invention is determined such that it is sufficiently high to prevent significant current leakage between elements of the patterned second electrode layer, but is not so high as to significantly increase the voltage required to operate the device.

The use of a material comprising a physical blend of an insulator material and a semiconductor material, or a physical blend of a semiconductor material and a conductor material or a physical blend of a conductor material and an insulator material as the barrier layer has the significant advantage that the resistivity of the layer can be readily adjusted in accordance with the requirements of the individual device by appropriately varying the relative proportion of each material in the blend.

The high resistance first electrode layer of this seventh aspect of the present invention is preferably composed of a physical blend of a conductor and an insulator or semiconductor, preferably a physical blend of a conductor and an insulator, since the increased conductivity of the blend realised by the inclusion of a conductor material means that the thickness of the high-resistance first electrode layer can be increased without causing a significant increase in the voltage

required to operate the device. This ability to substantially increase the thickness not only provides the possibility to enhance the protection of the underlying organic layer or layers from the effects of etching/ashing processes but also provides the means to compensate for the adverse effects of any defects (such as particles of contamination or pinholes) which inevitably exist in the underlying organic film even with the high degree of cleanliness provided by the modern clean room. For example, covering any such defects substantially reduces the existence of undesirable low-resistance pathways within the device, thereby improving the performance of the device. A barrier layer of increased thickness also provides increased protection of the underlying organic layer against the ingress of reactive ambient species such as moisture and oxygen which can react with the organic material resulting in black spots.

Suitable semiconductor materials include, but are not limited to, Ge, Si, α-Sn, Se, ZnSe, ZnS, GaAs, GaP, CdS, CdSe, MnS, MnSe, PbS, ZnO, SnO, TiO_2, TiO_2, MnO_2 and SiC.

Suitable insulator materials include, but are not limited to, oxides, nitrides and halides such as fluorides. The insulator material is preferably selected from the group consisting of Al_2O_3, SiO_2, LiO, AlN, SiN, LiF and CsF.

Suitable conductor materials include, but are not limited to, metals, preferably Al or Ag.

According to an embodiment of the seventh aspect of the present invention, the first electrode layer forms the cathode of the device and comprises at least one material comprising an element having a low work function (preferably 3.7eV or less, and further preferably 3.0eV or less) such as Li , Ca or Cs whereby the electron injecting performance of the electrode is enhanced. Electrode layers comprising a material including Li or Ca are particularly preferred. The first electrode layer is preferably comprised of a mixture selected from the group consisting of LiF/Al, Ca/Ge, Li/Si, Ca/ZnO, LiF/ZnSe and CsF/ZnS.

According to an alternative embodiment of the seventh aspect of the present invention, the first electrode layer forms the anode of the device and comprises at least one material including an element having a high work function (preferably greater than 4.5eV and further preferably greater than 5.0eV) whereby the hole injecting performance of the electrode is enhanced. In this alternative embodiment, it is preferred that the first electrode layer comprises a material selected from the group consisting of Au, Pd, Ag and indium-tin oxide (ITO).

The first electrode layer preferably has a thickness in the range of 0.5 to 1.0 microns, and is composed of a material having a resistivity, ρ in the range of 10^2 to 10^5 Ω.cm.

According to an eighth aspect of the present invention, there is provided an organic light-emissive device comprising a light-emissive organic region interposed between first and second electrodes for injecting charge carriers into the light-emissive organic region, at least one of said first and second electrodes comprising a plurality of layers including a high-resistance first electrode layer adjacent the surface of the light-emissive organic region remote from the other of the first and second electrodes, said first electrode layer formed over substantially the entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes, and having a thickness greater than the light-emissive organic region whereby adverse effects of any defects in the light-emissive organic region are compensated for by the first electrode layer; and a second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic region, said second electrode layer comprising a patterned conductive layer.

In this eighth aspect of the present invention, the thickness of the first electrode layer is preferably in the range of 0.5 to 1 micron; and the first electrode layer preferably comprises a material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material and an insulator, a mixture of a semiconductor material and a conductor material and a mixture of an insulator material and a conductor material.

According to a ninth aspect of the present invention, there is provided a method of forming an electrode of an organic light-emissive device comprising a light-emissive organic region interposed between first and second electrodes for injecting charge carriers into the light-emissive organic region, the method comprising forming one of the first and second electrodes by first forming a high-resistance first electrode layer over substantially the entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes, said first electrode layer comprising a material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material; and then forming a second electrode layer on the surface of said first electrode layer remote from the light-emissive organic region, said second electrode layer comprising a patterned conductive layer.

According to a tenth aspect of the present invention, there is provided an organic light-emissive device comprising a light-emissive organic region interposed between first and second electrodes for injecting charge carriers into the light-emissive organic region, at least one of said first and second electrodes comprising: a first electrode layer comprising an insulator material adjacent the surface of the light-emissive organic region remote from the other of the first and second electrodes; a high-resistance second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic region; and a patterned conductive third electrode layer adjacent the surface of said second electrode layer remote from the first electrode layer; wherein said first and second electrode layers cover substantially the entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes; and said second electrode layer comprises a high-resistance material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material.

In this tenth aspect of the present invention, the term "patterned electrode layer" refers to a plurality of electrode elements which are only connected to each other via the underlying electrode layers, and are preferably only connected to each other via the underlying high resistance second electrode layer.

The provision of a thin layer of an insulator material adjacent to the organic light-emissive region as well as an overlying high-resistance electrode layer has the following additional advantage. The charge carrier injecting performance can be further enhanced at the interface between the electrode and the light-emissive organic region by using a material containing a low work function element in the case of a cathode or a material containing a high work function element in the case of an anode without significantly increasing the operating voltage of the device and detracting from the function of the first and second electrode layers as a whole which is to prevent lateral current leakage (cross-talk) as well as protecting the underlying organic region.

In this tenth aspect of the present invention, the first electrode layer preferably comprises a layer of a dielectric oxide, nitride or halide such as a fluoride. Particularly preferred materials for use in the case of cathodes are LiO, LiF and CsF.

In each of the seventh to tenth aspects of the present invention, the light-emissive organic region may, for example, be composed of a single layer of a light-emissive organic material such as a light-emissive polymer, or it may include one or more additional organic layers which may function as additional light-emissive layers or as charge injection and/or transport layers.

Brief Description of the Drawings

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:-
Figure 1 is a cross-sectional view of an OLED according to an embodiment of the present invention;

Figure 2 is a cross-sectional view of an OLED for explaining the principle of one aspect of the present invention;

Figure 3 is a schematic cross-sectional view of an OLED having a typical defect site caused by particulate contamination of the organic material during spin-coating;

Figure 4 is a cross-sectional view of an OLED according to another embodiment of the present invention;

Figure 5 shows a schematic view of a light-emissive device according to another embodiment of the present invention;

Figure 6 is a schematic plan view of a section of the anode layer of the device shown in Figure 5;

Figure 7 is a cross-sectional view of a device according to another embodiment of the present invention; and

Figure 8 is a cross-sectional view of a device according to another embodiment of the present invention.

Description of the Preferred Embodiments

Figure 1 shows an OLED according to a first embodiment of the present invention. A glass substrate 2 having a thickness of 1.1mm is coated with a layer 4 of indium tin oxide (ITO) with a sheet resistance of 15 Ohms/sq. to a thickness of 150nm. Although not shown in Figure 1, this is patterned to form a series of parallel strips using, for example, standard photolithographic and etch processes. A layer 6 of polyethylenedioxythiophene doped with polystyrene sulphonic acid (PEDT:PSS) is spun on the anode layer 4 and subsequently baked at 150°C to remove water leaving a layer of 50nm thickness. A layer 8 of a light-emissive polymer such as a blend of 5% poly(2,7-(9,9,di-n-octylfluorene)-3,6-(benzothiadiazole) with 95% poly(2,7-(9,9-di-n-octylfluorene) (5BTF8) doped with poly(2,7-(9,9-di-n-octylfluorene)-(1,4-phenylene-((1,4-phenylene-((4-secbutylphenyl)imino)-1,4-phenylene)) (TFB) is then spun on to the layer 6 of PEDT:PSS to a thickness of 75nm. A cathode layer 10 is then formed on the layer 8 of light-emissive polymer.

A standard vacuum thermal evaporation technique is used to deposit the cathode layer in view of the fact that, being a relatively low-energy technique, it causes

minimal damage to the underlying layer of light-emissive polymer. If the possibility of damage to the underlying organic layer is not a concern, sputtering is a desirable technique because it is a conformal deposition technique. In the case of sputtering, neon is preferably used as the discharge gas.

In this case, the cathode layer 10 is a layer of LiF co-evaporated with Al. This cathode layer 10 is deposited to a thickness of between 0.5 and 1 micron to ensure that the entire surface of the underlying organic layer, and hence any defects therein, is covered by the cathode layer.. A layer 12 of aluminium is deposited on top of this layer to a thickness of 0.5 microns. This top layer of aluminium 12 can, for example, be deposited by evaporation. Although not shown in Figure 1, the cathode comprising the LiF-Al cathode layer 10 and the aluminium top layer 12 is also patterned in the form of a series of parallel strips running in a direction orthogonal to the series of parallel anode strips, whereby an ordered array of pixels is formed defined by the points at which each series of cathode and anode strips overlap.

The LiF has a dual function. It is a low work function material and therefore assists the injection of electrons into the light-emissive organic layer. It is also an insulator resulting in a layer having a high resistance.

The high-resistance LiF/Al layer conducts via a percolation mechanism.

The relative proportions of LiF and Al in the LiF-Al layer 10 will be determined according to the desired resistivity. The desired resistivity is itself determined according to the number and area of the defects existing in the underlying light-emissive organic layer 8. A method for determining a suitable resistivity is described below with reference to Figure 2 which shows an OLED comprising a light-emissive organic layer 18 containing a plurality of pinhole defects 30 which are the major cause of current anomalies in OLEDs.

The light-emissive organic layer 18 is sandwiched between a first cathode layer 20 and an ITO anode layer 14 coated on a glass substrate 12. The first cathode layer is coated with a layer of aluminium 22.

It is supposed, by way of example, that the current density (j) of the device at a typical operating voltage of 3V would be $1\mathrm{mA/cm^2}$ if the light-emissive organic layer 18 did not contain any pinhole defects.

It is desired that the current density attributable to the existence of the pinhole defects represents only a small proportion of the current density that would be observed if there were no pinholes existing in the light-emissive organic layer. For example, it is preferred that the first cathode layer is of a sufficiently high resistance that the current density attributable to the defects is at most 1% of the current density that would be observed if there were no pinholes existing in the light-emissive organic layer.

The current density through the pinhole defects can be calculated to be:

$j_{(def)} = NVA/\rho t$

where N is the density of defects (per unit area); A is the average area of each defect; V is the operating voltage; ρ is the resistivity of the cathode layer; and t is the thickness of the first cathode layer 20.

Let us now suppose that the thickness of the first cathode layer 20 is 0.5 microns, and that there are 100 defects each of area $1\mu m^2$.

Then, at the operating voltage of 3V mentioned above, the current density attributable to the defects would be approximately $60/\rho$ $\mathrm{mA/cm^2}$.

In order for this current density to represent 1% or less of the current density that would be observed if there were no pinhole defects (which is supposed as above to be $1\mathrm{mA/cm^2}$), the resistivity of the material of the first cathode layer would have to be about 6000Ωcm or greater.

The voltage drop across a first cathode layer having a thickness of 0.5 microns and composed of material having a resistivity of 6000Ωcm would only be about 0.3mV when the current density is $1\mathrm{mA/cm^2}$. This layer will therefore have a

negligible effect on the power efficiency whilst improving the uniformity of the current density of the OLED in operation.

The existence of particle defects in the light-emissive organic layer have been ignored on the basis that their effect is negligible compared to that of the pinhole defects. However, if the effects of any such defects are not negligible, it will be clear to the skilled person in light of the above how to take the effect of such particle defects into consideration when determining a suitable resistivity for the high resistance cathode layer.

Hereunder is provided a method for calculating the optimum value of resistivity for the high resistance layer for a device of the kind shown in Figure 1 with defective areas that would, without this high resistance layer, allow direct connection between the low resistance cathode and anode. The film is optimised for maximum efficiency.

For a device with no defects operating at a current density of I_0 (mA/cm^2) and voltage V_0 (Volts) with luminosity L_0 (Cd/m^2) has a luminous efficiency η_0 (lm/W) of

$$\eta_0 = \frac{\pi L_0}{10 V_0 I_0}. \tag{1}$$

If we now introduce defects into the device where the defective area as a ratio of the total area is D and the areal resistance of these defects is R_D (kΩ cm^2), the average current density through the whole device at the same voltage is

$$I = (1-D)I_0 + D\frac{V}{R_D}. \tag{2}$$

If we assume that the defective areas do not emit any light then the light emitted by the defective light-emissive organic layer is just given by

$$L = (1-D)L_0. \tag{3}$$

If we now introduce a high resistance cathode layer with areal resistivity R_H (kΩcm^2) then to get I_0 flowing through the non-defective areas, the voltage across the device needs to be increased to

$$V = V_0 + I_0 R_H. \tag{4}$$

The average current density flowing through our device is from equation 2

$$I = (1-D)I_0 + D\frac{V}{R_D + R_H}. \tag{5}$$

The new efficiency η is then given by combining equations 3,4 and 5 to give

$$\eta = \frac{\pi(1-D)(R_D + R_H)L_0}{10(V_0 + I_0R_H)\{(1-D)(R_D + R_H)I_0 + D(V_0 + I_0R_H)\}}. \tag{6}$$

In general, if the defective areas are a problem then they will have a very low resistance compared to the high resistance layer, i.e.

$$R_D \ll R_H. \tag{7}$$

The efficiency then becomes

$$\eta = \frac{\pi(1-D)R_H L_0}{10(V_0 + I_0R_H)\{(1-D)R_H I_0 + D(V_0 + I_0R_H)\}}. \tag{8}$$

If we differentiate this with respect to R_H to find the maximum efficiency we find that

$$R_H{}^{MAX} = \frac{\sqrt{D}V_0}{I_0}. \tag{9}$$

The value of the high resistance layer that maximises the efficiency at a particular operating point (determined by I_0 and V_0) depends on the square root of the fractional defective area.

The optimum resistivity of the high resistance layer will depend on the thickness of the high resistance layer which is in turn determined according to the size and shape of the defect causing the short and the method of deposition of the high resistance layer. If the method of deposition is one which covers all surfaces conformally then the high resistance layer can be any thickness. If however the method of deposition is a line of sight method such as evaporation from a fixed source to a fixed target then the thickness has to be, in general, greater than the height of the defect. If the thickness of the high resistance layer is taken to be t_H (in cm) and the optimum resistivity ρ_H then

$$\rho_H = \frac{R_H^{MAX}}{t_H}. \qquad (10)$$

It is thus clear that the optimum values of thickness and resistivity of the high resistance layer depend on the size of the defective area, the nature of the defect, the deposition method and the operating point of the device.

Figure 4 is a cross-sectional view of an organic light-emitting device according to another embodiment of the present invention. The substrate 202, anode layer 204, organic layers 206, 208 are identical to those of the first embodiment described above. A thin layer of calcium 209 having a thickness of 5nm is formed on the surface of the organic layer 208. This layer 209 is preferably formed by vacuum evaporation. A layer of silicon 210 having a thickness of 0.5 microns is formed on the thin layer of calcium 209 as a high-resistance layer, and a layer of aluminium 212 having a thickness of 0.5 microns is formed on top of the layer of silicon 210.

The use of a thin layer of a conductor material (in this case, calcium) between the high-resistance layer and the light-emissive organic layer is advantageous as it effectively acts as a fuse. If a portion of the thin conductor layer is subject to an anomalously high current as result of a defect in the portion of the organic layer underlying that portion of the thin conductor layer, that portion of the thin conductor layer vapourises thereby stopping current flowing through the conducting defect and improving the performance of the device. The conducting

defects can be isolated in this way by passing a high current through the device after production is completed.

Although the embodiments described above are devices having a high-resistance cathode, alternatively a high-resistance anode can be employed in the case, for example, that an OLED is produced by first forming a cathode on a glass substrate, depositing a layer of light-emissive organic material on the cathode by spinning, and finally forming an anode on the light-emissive organic layer. In the case of an anode, it is preferred that the high-resistance electrode layer comprises a high work function material, or that a thin layer of a high work function material is interposed between the high-resistance electrode layer and the light-emissive organic layer.

With reference to Figure 5, there is shown a light-emissive device according to the sixth aspect of the present invention for use in the light-emitting display according to the fifth aspect of the present invention. This device is intended for use as a backlight. It comprises a glass substrate 302, an anode layer 304 deposited on the glass substrate 302, an organic hole transport layer 306 deposited on the anode layer 304, an electroluminescent polymer layer 308 deposited on the hole transport layer 306, and a continuous metallic cathode layer 310 deposited on the electroluminescent polymer layer 308. Figure 6 shows a schematic plan view of a section of the anode layer as deposited on the glass substrate to illustrate the nature of the patterning of the anode layer 304. It comprises an ordered two-dimensional array of small sub-electrodes 320 arranged to form an array of parallel rows and columns. Each of the co-planar sub-electrodes is formed under a different portion of the hole transport layer 306. The dimension of the area of these sub-electrodes and the spacing between them is made small enough that a viewer of the light produced by the device cannot detect them under normal viewing conditions. Each of the sub-electrodes 320 is connected to those sub-electrodes directly adjacent to it in the same row and column by a fusible link 322. The material and dimensions of each fusible link are selected such that under normal operating conditions very little voltage is dropped across the fusible link, but such that, if subject to an anomalously high current (caused, for example, by a defect in the portion of the organic layers situated between the cathode and the sub-electrode), it

will overheat and blow thereby isolating the defective site from the rest of the backlight, with a resulting improvement in the performance of the device.

The sub-electrodes of the anode and the fusible links can, for example, be made of indium-tin oxide (ITO). The patterned array formed by the sub-electrodes and fusible links can, for example, be formed by first depositing a continuous layer of ITO on the glass substrate and then selectively etching the continuous layer using for example, a photolithographical technique, to form the patterned array. Alternatively, the sub-electrodes and the fusible links may be made of different materials.

The cathode may additionally or alternatively be formed of sub-electrodes connected by fusible links in the same manner as described above for the anode. However, in the type of device described above in which the cathode layer is deposited on top of the relatively sensitive organic layers, care normally has to be taken not to cause undue damage to the underlying organic layers. For this reason, it is preferable that the patterned cathode layer be formed by deposition through a shadow mask rather than by an etching technique.

Another embodiment of a light-emissive organic device according to the present invention is shown in Figure 7. In this embodiment, a glass substrate 402 of thickness 1.1mm is coated with indium tin oxide (ITO) 404 , which has a sheet resistance of 15 Ohms/sq., to a thickness of 150nm. This coating 404 of ITO is patterned to form a series of parallel rows using standard photolithographic and etch processes. A layer 406 of polyethylenedioxythiophene doped with polystyrene sulphonic acid (PEDT/PSS) is then formed on the ITO/glass substrate by spin-coating and baked at 150°C to remove water leaving a layer 406 having a thickness of 50nm. A layer 408 of light-emissive polymer is then deposited onto the layer 406 of PEDT/PSS also by spin coating. This layer could be a layer of a blend of 5% of poly(2,7-(9,9-di-n-octylfluorene)-3,6-(benzothiadiazole) and 95% of poly(2,7-(9,9-di-n-octylfluorene) (5BTF8) doped with poly(2,7-(9,9-di-n-octylfluorene-(1,4-phenylene-((1,4-phenylene-((4-secbutylphenyl)imino)-1,4-phenylene)) (TFB) and has a thickness of 75nm. A layer 410 of a LiF/Al blend is then deposited on to the layer 408 of light-emissive polymer by the co-evaporation

of LiF with Al in a vacuum chamber to form an ohmic contact on the light-emissive polymer layer 408. The LiF/Al blend layer 410 is deposited to a thickness sufficient to cover any defects on the surface of the light-emissive polymer layer 408. In the case that the device is prepared in a class 100 clean room, the thickness would be between 0.5 and 1 micron. An aluminium layer 412 is then deposited over the layer 410 of LiF/Al to a thickness of 0.5 microns, and is patterned using conventional photolithographic techniques to form a series of regularly spaced parallel columns running in a direction orthogonal to the series of parallel rows of ITO to thereby define a regular matrix of pixels where the series of ITO rows and Al columns spatially overlap with each other.

The LiF/Al physical blend is an isotropic conductor which conducts via a percolation mechanism wherein the resistivity of the blend is determined by the relative proportion of Al in the LiF/Al blend. The relative proportions of LiF and Al in the LiF/Al blend layer are determined according to the desired resistivity of the layer. The desired resistivity will of course vary according to the required thickness of the layer but is basically determined to provide a layer which is not so high in resistance that it leads to a significant increase in the drive voltage (since this will reduce the power efficiency of the device) but is high enough in resistance to ensure that crosstalk between adjacent columns is reduced to an insignificant level. The desired resistivity will therefore depend on several factors such as the number and spacing of the aluminium columns (which will depend on the desired resolution), the voltage at which each column is sequentially driven relative to adjacent columns, and the current density at which the device is to be operated.

Although a standard back-light LED is operated at a relative low current density of typically 1mA/cm^2, the operating current density of a dot-matrix display LED will often be higher because , for example in a passive matrix device, the rows are driven sequentially. Typically, the higher current density will correspond to the unpulsed current density (the current density at which the device would be operated if it were to be used as a back-light device) multiplied by the number of rows which are sequentially driven. Therefore, a device having 100 rows will typically be operated at a current density of 100mA/cm^2.

If the layer were to have a thickness of 0.5 microns, the resistivity of the LiF/Al blend could be up to 2 x 10^4 Ohm.cm without leading to an increase in drive voltage of greater than 0.1V, and if an increase in drive voltage of up to 1V were to be acceptable, the resistivity of the LiF/Al blend could be up to 2 x 10^5 Ohm.cm. If a layer having a thickness of 0.5 microns and a resistivity of 2 x 10^5 Ohm.cm were employed in a device in which the overlying aluminium layer and ITO anode layer were respectively patterned to form columns and rows each having a pitch of 1mm, a spacing of 0.5mm and a length of 50mm, then the leakage current to the adjacent columns on either side of the driven column is only 0.5μA (based on the supposition that the driven column is at 10V and the adjacent columns on either side of the driven column are earthed) compared to the current though the device of 250μA when only a single pixel is lit.

The embodiment described above also has the advantage that the high-resistance layer between the aluminium layer and the light-emissive organic layer comprises a material, LiF, which contains a low work function element and thus aids the injection of electrons into the light-emissive polymer, thereby improving the performance of the device.

Another embodiment of the organic light-emissive device according to the present invention is shown in Figure 8. The device shown in Figure 8 is identical to that shown in Figure 7 with respect to the substrate, anode and organic layers, and identical reference numerals are used to denote identical components. The device shown in Figure 8 differs from the device shown in Figure 7 with respect to the construction of the cathode. The cathode comprises a layer 414 of lithium fluoride having a thickness of about 5nm. This layer 414 can be deposited by any conventional deposition technique but is preferably deposited by a thermal evaporation technique to minimize the damage to the underlying organic layer. On top of this thin layer 414 of lithium fluoride is deposited a layer 416 of a semiconductor material such as a layer of a physical blend of lithium fluoride and aluminium to a thickness in the range of 0.5 to 1 micron. Next, a layer 412 of aluminium is deposited to a thickness of 0.5 microns on top of the layer 416 of lithium fluoride/aluminium blend to form an ohmic contact. This layer 412 of

aluminium is then patterned using conventional patterning techniques to form a series of parallel columns running in a direction orthogonal to the series of anode rows. The relatively thick layer 16 of lithium fluoride/aluminium blend ensures the underlying organic layer is adequately protected from the patterning processes. The resistance of the aluminium/lithium fluoride blend layer 416 is such that it does not raise the operating voltage of the device by an intolerable degree whilst still preventing lateral current leakage (cross-talk) between adjacent cathode columns. The provision of a thin layer 414 of lithium fluoride adjacent the light-emissive organic region enhances the injection of electrons from the cathode into the light-emissive organic region.

Although the embodiments shown in Figures 7 and 8 show the use of a high-resistance electrode layer with a patterned cathode, it could equally be used together with a patterned anode in the case that an OLED is produced by first forming a patterned cathode on a glass substrate, depositing one or more layers of organic material on the cathode, and finally forming an anode on the uppermost layer of organic material. In the case of an anode, it is preferred that the electrode layer adjacent the light-emissive organic region comprises at least one element having a high work function to enhance the injection of positive charge carriers (holes) into the light-emissive organic region from the anode.

CLAIMS

1. An organic light-emitting device comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer and means for limiting the current flow through any conductive defect in said light-emissive organic layer.
2. An organic light-emitting device according to claim 1 wherein said means are incorporated into at least one of said first and second electrodes.
3. An organic light-emitting device according to claim 2 wherein said at least one of said first and second electrodes comprises a plurality of layers including a first electrode layer adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes and having a resistance selected such that it is not too high to cause a significant increase in the drive voltage of the device, yet high enough to prevent excessive currents at any conductive defect in said light-emissive organic layer.
4. An organic light-emitting device according to claim 3 wherein said first electrode layer comprises a high-resistance material selected from the group consisting of a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material.
5. An organic light-emitting device comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer, at least one of said first and second electrodes comprising a plurality of layers including a first electrode layer having a high resistance adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes, said first electrode layer comprising a high-resistance material selected from the group consisting of a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material.
6. An organic light-emitting device according to any preceding claim wherein the first electrode layer comprises at least one material having a low work function.

7. An organic light-emitting device according to any preceding claim wherein the semiconductor material is selected from the group consisting of Ge, Si, α-Sn, Se, ZnSe, ZnS, GaAs, GaP, CdS, CdSe, MnS, MnSe, PbS, ZnO, SnO, TiO_2, TiO_2, MnO_2 and SiC, or wherein the insulator material is selected from the group consisting of an oxide, a nitride and a fluoride, preferably from the group consisting of Al_2O_3, SiO_2, LiO, AlN, SiN, LiF and CsF.
8. An organic light-emitting device according to any preceding claim wherein the conductor material is a ductile metal and preferably is selected from the group consisting of Al and Ag.
9. An organic light-emitting device according to any preceding claim wherein the first electrode layer is comprised of a mixture selected from the group consisting of LiF/Al, Ca/Ge, Li/Si, Ca/ZnO, LiF/ZnSe and CsF/ZnS.
10. An organic light-emitting device comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer and means for electrically isolating any conducting defect in the organic layer from an associated electrode.
11. An organic light-emitting device according to claim 10 wherein said means are incorporated into at least one of said first and second electrodes.
12. An organic light-emitting device according to claim 11 wherein said at least one of said first and second electrodes comprises a plurality of layers including a thin first electrode layer adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes, the dimensions and material properties of said thin first electrode layer being chosen such that, adjacent a conducting defect in said organic layer, said layer will vapourise when subject to an anomalous current resulting from said conducting defect.
13. An organic light-emitting device according to claim 12, at least one of said first and second electrodes being opaque and comprising a plurality of layers including a thin first electrode layer comprising a low work function material adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes, and a second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic layer, said second electrode layer comprising a layer of a high-resistance material selected from the group consisting of a semiconductor material, a mixture of a

semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material and a conductor material.

14. An organic light-emitting device according to claim 12, comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer, at least one of said first and second electrodes comprising a plurality of layers including a thin first electrode layer comprising a high work function material adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes, and a second electrode layer adjacent the surface of the first electrode layer remote from the organic light-emissive material, said second electrode layer comprising a layer of a high-resistance material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material.

15. An organic light-emitting device comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer, at least one of said first and second electrodes being opaque and comprising a plurality of layers including a thin first electrode layer comprising a low work function material adjacent the surface of the light-emissive organic layer remote from the other of the first and second electrodes, and a second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic layer, said second electrode layer comprising a layer of a high-resistance material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material and a conductor material.

16. An organic light-emitting device comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer, at least one of said first and second electrodes comprising a plurality of layers including a thin first electrode layer comprising a high work function material adjacent the surface of the light-

emissive organic layer remote from the other of the first and second electrodes, and a second electrode layer adjacent the surface of the first electrode layer remote from the organic light-emissive material, said second electrode layer comprising a layer of a high-resistance material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material.

17. An organic light-emitting device according to claims 12 or 13 further comprising a third electrode layer on the surface of the second electrode layer remote from the first electrode layer, said third electrode layer comprising a conductor material, preferably a ductile metal.
18. An organic light-emitting device comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer, at least one of said first and second electrodes comprising a plurality of layers including a first electrode layer having a high resistance, said first electrode layer having a thickness greater than the light-emissive organic layer, such that any intrinsic defects in the light-emissive organic layer are covered by the first electrode layer.
19. An organic light-emitting device according to claim 18 further comprising a second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic layer, said second electrode layer comprising a layer of a conductor material.
20. An organic light-emitting device according to claims 18 or 19 wherein the thickness of the first electrode layer is in the range of 0.5 to 1 micron.
21. An organic light-emitting device according to claim 18 wherein the first electrode layer comprises a material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material and an insulator, a mixture of a semiconductor material and a conductor material and a mixture of an insulator material and a conductor material
22. A method for improving the uniformity of current density of an organic light-emitting device comprising a light-emissive organic layer interposed between first and second electrodes for injecting charge carriers into the light-emissive organic layer, the method comprising the step of forming one of the first and

second electrodes from a plurality of electrode layers including a first electrode layer having a high resistance, said first electrode layer comprising a material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material.

23. A light-emissive device comprising a layer of light-emissive material arranged between first and second electrode layers such that charge carriers can move between the first and second electrode layers and the light-emissive material, wherein at least the first electrode layer comprises a plurality of sub-electrodes, each sub-electrode being connected to each of any sub-electrodes directly surrounding it via a fusible link, each fusible link adapted to break when subject to a current exceeding a specified value to electrically isolate the respective sub-electrode from the other sub-electrodes.

24. A light-emissive device according to claim 11 and wherein said at least one of said first and second electrodes comprises a plurality of sub-electrodes, each sub-electrode being connected to each of any sub-electrodes directly surrounding it via a fusible link, each fusible link adapted to break when subject to a current exceeding a specified value to electrically isolate the respective sub-electrode from the other sub-electrodes.

25. A light-emissive device according to claim 23 or 24 wherein the plurality of sub-electrodes are arranged to create an ordered array of parallel rows and columns, and each of the sub-electrodes is connected via a fusible link to each of any sub-electrodes directly adjacent to it in the same column and row.

26. A light-emissive device according to any of claims claim 23 to 25 wherein the size and spacing of the sub-electrodes is selected such that, during operation of the device, the light emitted by the light-emissive device appears to the human eye to be continuous in intensity across the whole area of light emission.

27. An organic light-emissive device comprising a light-emissive organic region interposed between first and second electrodes for injecting charge carriers into the light-emissive organic region, at least one of said first and second electrodes comprising: a high-resistance first electrode layer adjacent the surface of the light-emissive organic region remote from the other of the first and second electrodes, said first electrode layer covering substantially the

entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes and comprising a high-resistance material selected from the group consisting of a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material; and a patterned conductive second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic region.

28. An organic light-emissive device according to claim 27 wherein the first electrode layer comprises at least one material containing an element having a low work function.
29. An organic light-emissive device according to claim 28 wherein the element having a low work function is calcium or lithium.
30. An organic light-emissive device according to any of claims 27 to 29 wherein the semiconductor material is selected from the group consisting of Ge, Si, α-Sn, Se, ZnSe, ZnS, GaAs, GaP, CdS, CdSe, MnS, MnSe, PbS, ZnO, SnO, TiO, TiO_2, MnO_2 and SiC.
31. An organic light-emissive device according to any of claims 27 to 30 wherein the insulator material is selected from the group consisting of an oxide, a nitride and a fluoride.
32. An organic light-emissive device according to claim 31 wherein the insulator material is selected from the group consisting of Al_2O_3, SiO_2, LiO, AlN, SiN, LiF and CsF.
33. An organic light-emissive device according to any of claims 27 to 32 wherein the conductor material is a metal.
34. An organic light-emissive device according to claim 33 wherein the conductor material is selected from the group consisting of Al and Ag.
35. An organic light-emissive device according to any of claims 27 to 34 wherein the first electrode layer is comprised of a mixture selected from the group consisting of LiF/Al, Ca/Ge, Li/Si, Ca/ZnO, LiF/ZnSe and CsF/ZnS.
36. An organic light-emissive device according to any of claims 27 to 35 wherein the thickness of the first electrode layer is in the range of 0.5 to 1.0 microns.

37. An organic light-emissive device according to claim 27 wherein the first electrode layer comprises at least one element having a work function greater than 4.5eV.
38. An organic light-emissive device according to claim 37 wherein the first electrode layer comprises at least one material selected from the group consisting of Au, Pd, Pt and ITO.
39. An organic light-emissive device comprising a light-emissive organic region interposed between first and second electrodes for injecting charge carriers into the light-emissive organic region, at least one of said first and second electrodes comprising: a high-resistance first electrode layer adjacent the surface of the light-emissive organic region remote from the other of the first and second electrodes, said first electrode layer formed over substantially the entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes, and having a thickness greater than the light-emissive organic region whereby adverse effects of any defects in the light-emissive organic region are compensated for by the first electrode layer; and a patterned conductive second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic region.
40. An organic light-emissive device according to claim 39 wherein the thickness of the first electrode layer is in the range of 0.5 to 1 micron.
41. An organic light-emissive device according to claim 39 or claim 40 wherein the first electrode layer comprises a material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material and an insulator, a mixture of a semiconductor material and a conductor material and a mixture of an insulator material and a conductor material.
42. A method of forming an electrode of an organic light-emissive device comprising a light-emissive organic region interposed between first and second electrodes for injecting charge carriers into the light-emissive organic region, the method comprising forming one of the first and second electrodes by the steps of: first forming a high-resistance first electrode layer over substantially the entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes, said first electrode layer comprising a material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator, a mixture of

a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material; and then forming a patterned conductive second electrode layer over the surface of said first electrode layer remote from the light-emissive organic region.

43. An organic light-emissive device comprising a light-emissive organic region interposed between first and second electrodes for injecting charge carriers into the light-emissive organic region, at least one of said first and second electrodes comprising: a first electrode layer comprising an insulator material adjacent the surface of the light-emissive organic region remote from the other of the first and second electrodes; a high-resistance second electrode layer adjacent the surface of the first electrode layer remote from the light-emissive organic region; and a patterned conductive third electrode layer adjacent the surface of said second electrode layer remote from the first electrode layer; wherein said first and second electrode layers cover substantially the entire area of the surface of the light-emissive organic region remote from the other of the first and second electrodes; and said second electrode layer comprises a high-resistance material selected from the group consisting of a semiconductor material, a mixture of a semiconductor material with an insulator material, a mixture of a semiconductor material with a conductor material and a mixture of an insulator material with a conductor material.

44. An organic light-emissive device according to claim 43 wherein the first electrode layer comprises a layer of a dielectric material.

45. An organic light-emissive device according to claim 43 or claim 44 wherein the first electrode layer comprises a dielectric material containing a low work function element.

46. An organic light-emissive device according to claim 45 wherein the first electrode layer comprises a layer of at least one dielectric material selected from the group consisting of LiO, CsF and LiF.

47. An organic light-emissive device according to any of claims 43 to 46 wherein the semiconductor material is selected from the group consisting of Ge, Si, α-Sn, Se, ZnSe, ZnS, GaAs, GaP, CdS, CdSe, MnS, MnSe, PbS, ZnO, SnO, TiO, TiO_2, MnO_2 and SiC.

48. An organic light-emissive device according to any of claims 43 to 47 wherein the insulator material of the second electrode layer is selected from the group consisting of an oxide, a nitride and a fluoride.
49. An organic light-emissive device according to claim 48 wherein the insulator material of the second electrode layer is selected from the group consisting of Al_2O_3, SiO_2, LiO, AlN, SiN, LiF and CsF.
50. An organic light-emissive device according to any of claims 43 to 49 wherein the conductor material is a metal.
51. An organic light-emissive device according to claim 50 wherein the conductor material is selected from the group consisting of Al and Ag.
52. An organic light-emissive device according to any of claims 43 to 51 wherein the thickness of the second electrode layer is in the range of 0.5 to 1.0 microns.
53. An organic light-emissive device according to any of claims 43 to 52 wherein the thickness of the first electrode layer is less than 10nm.
54. An organic light-emissive device according to claim 53 wherein the thickness of the first electrode layer is less than 5nm.
55. An organic light-emitting device according to claim 1 wherein the thickness of the first electrode layer is in the range of 0.5 to 1.0 microns.
56. An organic light-emitting device according to claim 13 or 15 wherein the first electrode layer is comprised of a layer of a material selected from the group consisting of Ca, Li, Yb, LiF, CsF and LiO.
57. An organic light-emitting device according to any of claims 13 to 16 wherein the thickness of the first electrode layer is in the range of 0.5nm to 10nm, preferably less than 5nm.
58. An organic light-emitting device according to any of claims 1 to 9 wherein the organic light-emitting device further comprises a second electrode layer on the first electrode layer, said second electrode layer comprising a layer of a conductor material, preferably a layer of a ductile metal.
59. An organic light-emissive device substantially as described hereinbefore with reference to any of the accompanying drawings.

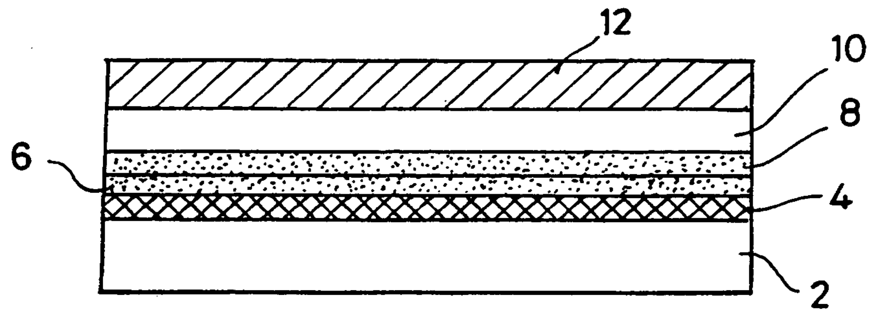

Fig. 1

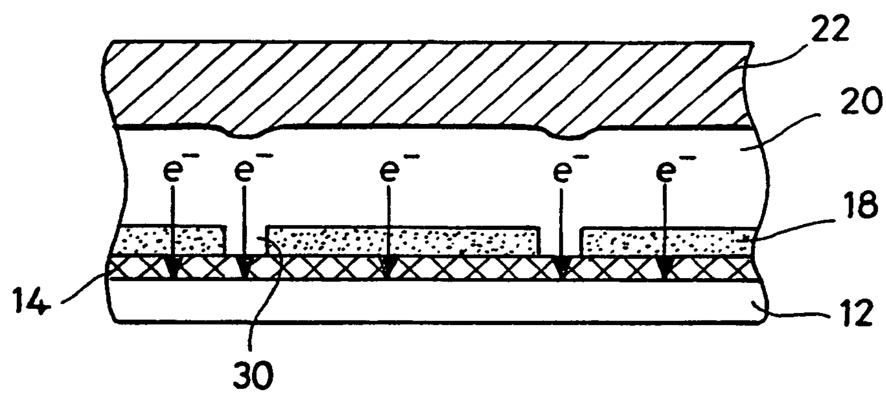

Fig. 2

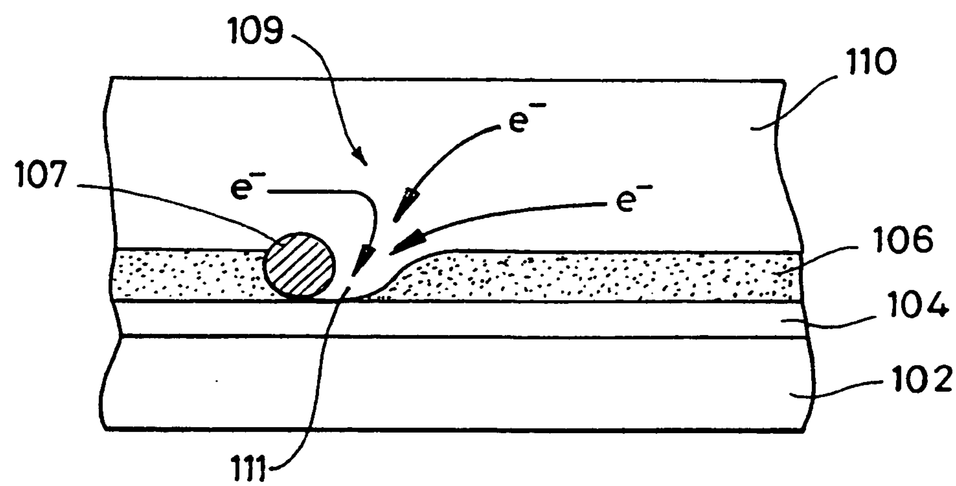

Fig. 3

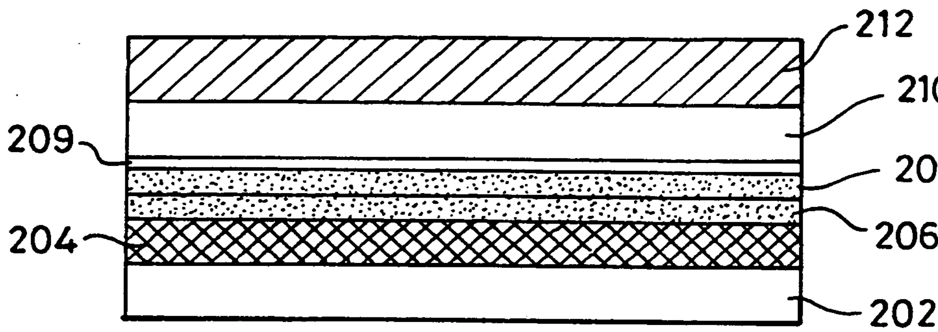

Fig. 4

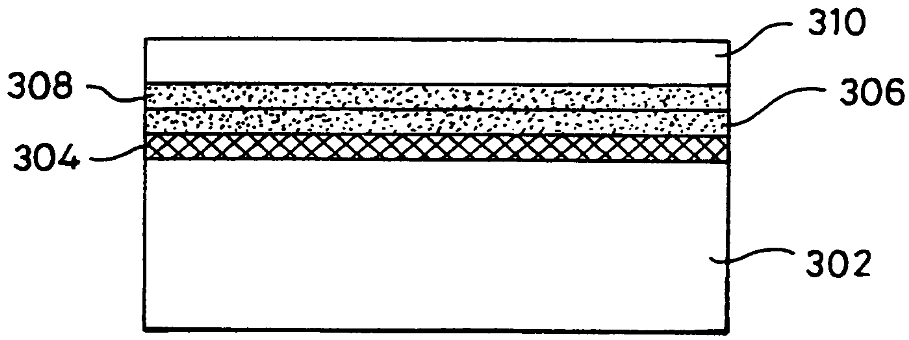

Fig. 5

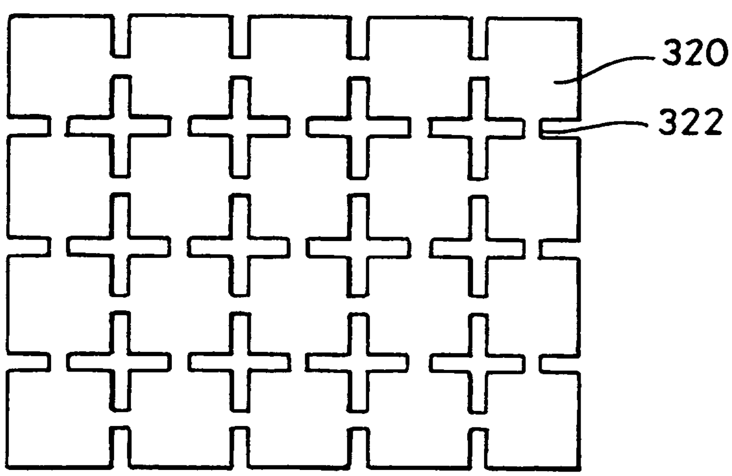

Fig. 6

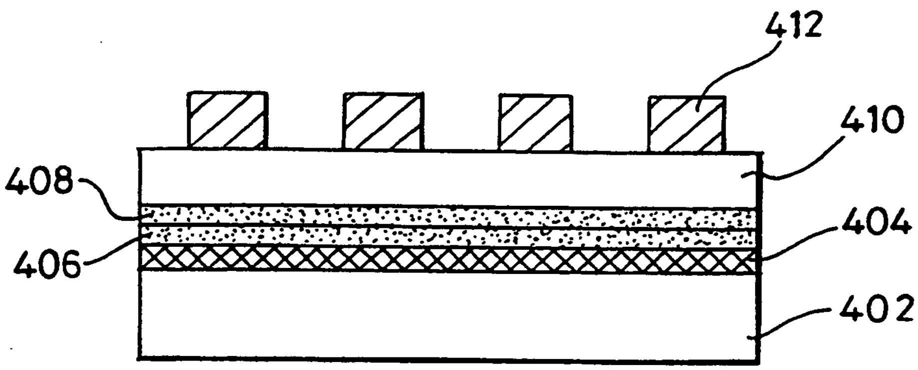

Fig. 7

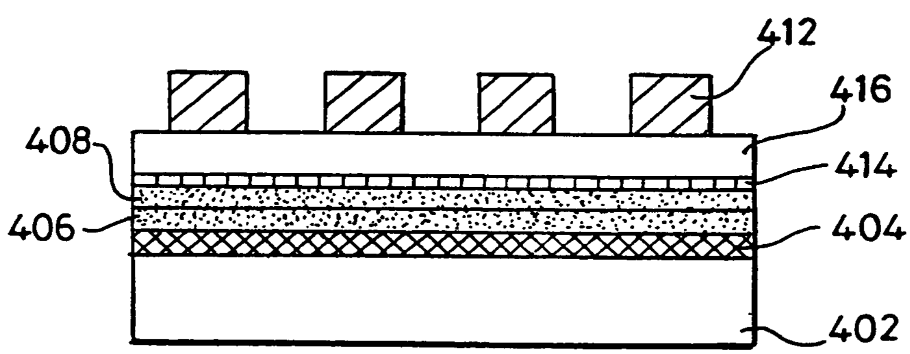

Fig. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 99/04150

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L51/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 647 813 A (KITABAYASHI MOTOI ET AL) 3 March 1987 (1987-03-03) the whole document ---	1-3,7,8, 10-13, 15,17, 22,56-59
Y	US 5 739 545 A (HAIGHT RICHARD ALAN ET AL) 14 April 1998 (1998-04-14) the whole document ---	1-3,7,8, 10-13, 15,17, 22,56-59
P,X	EP 0 901 176 A (CAMBRIDGE DISPLAY TECH) 10 March 1999 (1999-03-10) abstract --- -/--	1-3

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 March 2000	31/03/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Laere, A

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
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A	GYOUTOKU A ET AL: "Organic electroluminescent dot-matrix display using carbon underlayer" PROCEEDINGS OF THE 1997 INTERNATIONAL CONFERENCE ON ELECTROLUMINESCENCE OF MOLECULAR MATERIALS AND RELATED PHENOMENA;FUKUOKA, JPN MAY 21-24 1997, vol. 91, no. 1-3, 21 May 1997 (1997-05-21), pages 73-75, XP000890057 Synth Met;Synthetic Metals Dec 1997 Elsevier Science S.A., Lausanne, Switzerland page 73-75, paragraph 3	1-3
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